

GEOLOGICAL SURVEY OF NEW JERSEY.

ANNUAL REPORT

OF THE

STATE GEOLOGIST

FOR THE YEAR

1898.

TRENTON, N. J.
MACCRELLISH & QUIGLEY, STATE PRINTERS, OPPOSITE POST OFFICE.

1899.



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ERRATA.

- Page 19, line fourteen, read "northward" instead of "northwest."
Page 53, line eleven, read "along" instead of "above."
Page 54, line thirty, read "the" instead of "these."
Page 121, line nine, omit "F" at end of line.
Page 131, first line, read "Kreischerville" for "Krieshersville."
Page 133, first line, read "Demarest" for "Demerest."
Page 143, eleventh line from bottom, read "Kearney" for "Kearny."
Page 163, tenth line, read "15" instead of "5."

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* Died July 14, 1898.

*To His Excellency David O. Watkins, Acting Governor of the State of
New Jersey, and ex-officio President of the Board of Managers of
the Geological Survey:*

SIR—I have the honor to present herewith the Annual Report
of the Geological Survey for 1898.

Respectfully submitted,

JOHN C. SMOCK,

State Geologist.

TRENTON, N. J.

November 30, 1898.

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Administrative Report.

The plan of work of the Geological Survey for the year 1898, as presented in outline to the Board of Managers at the annual meeting in January, was followed along the the general lines of investigations and surveys of the several divisions of the work, and was practically a continuation of the work of 1897. The organization is the same as it was last year. Professor Rollin D. Salisbury has had the direction of the field surveys of the surface formations, and has given much time to the question of the publication of the results of his long-continued studies of the surface geology of the State. He has been assisted by G. N. Knapp. Dr. Henry B. Kümmel traced the Triassic red sandstones and trap-rocks of Bergen county northward beyond the State line to the Hudson river, and prepared a report on the extension of these rocks and the relation to the New Jersey area. Mr. Cornelius C. Vermeule has continued in charge of the topographic survey, and has prepared a report on "Water-Supply from Artesian Wells" and one on "The Pine Belt of Southern New Jersey and Water-Supply." He has been assisted by Mr. Peter D. Staats. The records of artesian wells in the State have been continued by Mr. Lewis Woolman. In co-operation with the United States Geological Survey, Dr. J. E. Wolff has given some time to the studies of the crystalline schists at Franklin Furnace and Ogdensburgh. The forestry survey has been carried forward on the basis of the original plan of the work, and a report on "Forest Fires and Wood Production" has been prepared for publication by Mr. Gifford Pinchot, Chief of the Division of Forestry, U. S. Department of Agriculture. Professor Arthur Hollick, of Columbia University, has continued his studies of the distribution of the trees of the State in their relation to the geological formations. Mr. Irving S. Upson remains in charge of the distribution of topographic maps, and also is the disbursing officer of the survey.

SURFACE GEOLOGY.

The study of the geology of the surface, and the mapping of the surface formations have been under the direction of Professor R. D. Salisbury. The field work is practically complete, and the publication of the results of the surveys of these formations is begun. The re-examination of local details will be necessary in places, for the preparation of the sectional maps, and further investigations of the extension of the formations beyond the limits of the State to the northeast and to the southwest will be desirable that the correlation be in harmony with geologic science. These studies may be made as the work of preparing the report and the maps goes forward. Professor Salisbury was in the field from the first of April to July. He was assisted by G. N. Knapp, who spent a month working in the territory of the Camden sheet, after which time he was engaged in preparing notes for the report on the soils of the State.

The report of the surface geology is to be in two parts or volumes, one on the northern part of the State and the other descriptive of the southern part. The last volume of the Geological Survey series on "The Physical Geography of the State" is an introduction to the subject, and the forthcoming reports are to form consecutive volumes of the series. One local map of the surface formations has been published, viz., Atlas Sheet No. 6, the Valley of the Passaic, with the country eastward to Newark and south to the Raritan river. It was issued with the annual report for 1894. The original plan of publication of the geological maps on the basis of the subdivision into seventeen sections or separate maps, conformable to atlas of topographical maps has been given up, and a new scheme has been prepared. The new plan has thirty-four maps conforming to the original projection sheets of the topographical survey. They are not to be overlapping, as is the case with the latter, but joining edge to edge, enabling the publisher to make up the transfer sheets with accuracy, and avoiding liability to errors from the use of more irregular parts of the original projection sheet. The scale is to be one inch to a mile, or the same as that of the topographic maps. The new form is more convenient for study and for office use, and by a combination of four sheets a convenient form and size is had for wall map. Such combination sheets will be valuable for the exhibition of the geology of many districts of the State where the single sheet

shows too small a territory. The new topographic surveys and the revision of the topographic maps are affording valuable additions for the base to be used in the geological series. As was said in the last annual report, the delay in the publication has resulted in the elaboration of a comprehensive plan, and allowed time for the revision of the base, where most needed. It has given opportunity to collect additional facts on the relations of geology to economics. The value of an accurate knowledge of the surface beds, and the economic application of the geological facts to the development of the natural resources—of the materials useful in the arts, of the soils and their capabilities, the water-supply, the forests and the scenic features in their bearing upon residential property, demand care in their illustration with accurate maps.

The report on the geology of the surface is to embrace all the facts of the occurrence and relation of the formations of the surface, both to one another and to the underlying rocks, and also their history and the origin or source of their materials. Short descriptions of the territory covered by the several maps may serve as hand-books or guides accompanying them. Two of these maps and the local descriptions have been prepared. The publication of the sectional maps and accompanying text or descriptive hand-books is designed to serve for local use and to meet the demands for particular information, instead of general reports on the State, or on a large division of the State. In a selective way the wants of a larger constituency are served than is possible without such sectional maps. The geological series promises to be as valuable as the topographical one has been, and to realize in full the original plan of the Geological Survey at the beginning of its work, of publishing accurate maps.

In the annual report for the year, Professor Salisbury has given an important contribution to our knowledge of the soils of the State, or of what might be considered as the top or uppermost layer of the surface formations and that part which is capable of producing crops.

The classification of the soils of the State in the descriptions published in the early reports of the Geological Survey was based upon the kind of rock or underlying formation, and the divisions were as follows: Gneiss or granite, limestone, slate, red sandstone and shale, marl, miocene, drift and alluvial.* The relation to the underlying rock formation and the origin of the soils and the chemical compo-

* Ann. Rep. of State Geologist for 1873, pp. 115-118. Ann. Rep. of State Geologist for 1879, pp. 103-115.

sition of typical specimens were given in these reports. Although the composition indicates a general relation to the rocks underlying them, the changes to which the surface formations, or covering of earth on the rocky floor, have been subjected in the long exposure to surface agencies have been such that the relation is one which cannot always be considered so intimate as to give character and serve as a basis for classification without qualification or many exceptions. Professor Salisbury has described the soils common to these geological formations as convenient and geographically well-marked groups or divisions, giving in some detail the variations due to the influence of the later geologic changes of the surface formations. The descriptions, as broadly outlined or indicated by the under or rock formations, are interpreted in the light of the later geologic history. The terms heavy and light, and clayey, loamy and sandy, are relative in application, as the types or standards of comparison vary from district to district, and in different parts of the State do not convey accurately the same meaning. There is, however, a general agreement in the use of these terms, so that they are convenient in description, although not strictly scientific or accurate.

The soils which are *residuary*, or the result of the disintegration or decomposition of the mineral constituents of the rock in place, are in any given formation, alike in character and conditions bearing upon their agricultural uses. The variation which arises from a wide range of minerals occurring in the rock, as is the case with the crystalline rocks, has to be considered in any full description of the soils of a crystalline rock district. The varieties which are thus produced are, however, not so largely chemical as physical in kind, being more or less alike in having the same chemical constituents and often in holding minute particles or fragments of the disintegrated rock. The alteration by weathering is changing gradually these fragmentary constituents into sands and clays, but in many cases the granular and apparently sandy soil is made up of these undecomposed rock fragments, and they indicate its relation to the parent formation.

The decomposition of the limestones favors more uniform character, except the white, crystalline variety, in which the presence of foreign minerals affects the resulting earthy surface or soil. The slates and the sandstones also afford less variety and the soils on them are not so diverse in character as those of the crystalline rocks. In the northern part of the State the sedentary soils are generally marked by

the presence in them of partially decomposed rock fragments. They are the marks showing the origin. It is a common observation to determine the kind of rock underneath by these fragments in the surface earth.

That great transforming agent, the ice-sheet of the glacial age and the waters of its melting and retreat, so planed off, ground down and transported the original surface and so mixed the loose materials that typical sedentary soils are limited to comparatively small areas. Even beyond the limits of the ice-sheet the effects are seen in the mixture of material by the floods of water along the river valleys and over low-lying plains. The survey of the surface formations has been necessary to an accurate description of the soils of the State, showing in detail the areas of these various formations of the surface and lying upon the rock formations. It is, as it were, also an agricultural survey of the State. The results, when published, with maps on a large scale, will show the nature of the surface and the soils. The map which accompanies this report is too small for anything more than to give a general representation of the principal divisions of the surface.

In the southern part of the State there is a wide diversity in the character of the soil and the intermixture of materials is greater than in the northern part, and the variation from point to point, excepting in the green-sand marl belt, makes any general descriptions impossible. Local variation is characteristic. Clays, sands and gravels in ever-varying proportions make up the surface layers and the soils.

The report of Professor Salisbury gives a good description of the soils and their local occurrence, and short notes on their capabilities and their adaptation to certain farm crops. Valuable suggestions on the forest covering also are referred to in this report. The steep sides of the hills and mountains in the northern part of the State, particularly in the glaciated or northern districts, should not be tilled and exposed to the wash of rains and floods, carrying the more valuable elements of the soil into the streams and making their otherwise clear and limpid waters muddy and unfit for water-supply to towns and cities, but should be kept in timber. The soils in these situations are best fitted for crops of wood. On the other hand the more clayey soil of some of the swampy districts can be made, by efficient drainage, into the best of farm land.

In the Red Sandstone belt the uniformly good soil has led to ex-

tensive clearing and the removal of nearly all the timber, particularly in the valley of the Raritan river. Fortunately the trap-rock ridges in this part of the State are so stony that they are generally left as woodland. The reference to the valuable timber trees which appear to thrive on these trap-rock soils is most important. The preservation of the woodlands on these ridges would be of public benefit to the Red Sandstone country and the timber would be the best crop to which to devote these trap-rock soils.

The open, gravelly soils of some of the valleys in the northern part of the State indicate their unfitness for tillage or pasturage, though generally now in farms, on account of the ease with which they were cleared originally, and the labor of clearing the more stony hills and mountains. The settlements followed the valleys in the Highlands, and the lands in them were cleared of the timber, without regard to the natural adaptation of the soil or its unfitness for profitable agriculture. If some of these valley lands were abandoned to wood, or, better, were devoted to timber-culture, the State would be richer in the sum total of natural assets.

The extremely sandy soils and gravels which are a feature of the surface of the Beacon Hill formation generally, are not fit for farming, except possibly in most favorable situations and near to markets and transportation lines. The unsuccessful struggle in many places is evidence of this ill-adaptation to agriculture. This part of Southern New Jersey is the territory which is indicated by its poverty of soil as a forest reservation and gathering-ground for water-supply.

The report on soils is not only descriptive of conditions, but is full of suggestions and a most important introductory chapter on the soils and agricultural capabilities of the State.

RED SANDSTONE—TRIASSIC—NEWARK SYSTEM OF ROCKS.

In the "Geology of New Jersey," 1868, the extension of the red sandstone, shale and trap-rocks of the Triassic age beyond the State line into New York was described and the geological map of the Triassic rocks was made to include this northeast extension to Stony Point on the Hudson river. The State line crosses the zone almost at right angles to the trend and has no relation to the natural features or the physical geography. The old estuary had its northern limit near the Hudson river at Stony Point. The later studies of this formation by

Dr. H. B. Kümmel, the results of which are given in his reports in 1896 and 1897, and published in the annual reports of the Geological Survey for those years, suggested the importance of extending the investigation to the limits of the formations in New York. It was hoped that some characteristic features or occurrences in the rocks would be found which might help to explain what had been observed in New Jersey near the State line, and add to our knowledge of the Triassic rocks in general. The results of the survey of the north-eastern extension of these rocks as made by Dr. Kümmel are given in Part II of this report. He made a detailed survey of the New York area, lying in Rockland county, for the State Geologist of New York, and through the courtesy of the late Professor James Hall, State Geologist, the present report is published. The north-west extension of the Palisade range is traced up the Hudson, passing Nyack and Haverstraw, then turning west and culminating in the High Tor, near Haverstraw. The absence of the mural front so characteristic of the New Jersey Palisades, the depressions of Short Clove and Long Clove as seen in the view, Plate II, are marked features of this range. The trap-rock breaking across the sandstone and shale, and the additional evidence of the intrusive origin of the trap-sheet, corroborate the work done on the range in this State. The marked ridge and valley structure in Bergen county in the red sandstone is traced northward, and the explanation is found in the varying hardness and resistance of the different beds to weathering and erosion. The absence of the rocks of the Lockatong division in Rockland county agrees with what was observed in Bergen county and is confirmatory of the absence of these argillites. The conglomeratic condition of the Brunswick beds also is notable as a variation from their shaly conditions in Bergen county generally. The coarse calcareous conglomerates at the northwest border make another mark of difference, indicative of diverse shore conditions on the old estuary. The alteration in the Stockton beds immediately under the trap-sheet of the Palisades is progressively less decided going northward into New York. The Ladentown outcrop of trap is demonstrated to be a separate eruptive mass and not continuous with the Palisades sheet. The evidences of faulting along the Highlands border, on the north-west, are decisive.

The report with that of last year on the northeastern part of the Newark system of rocks in this State, presents a complete view of the

Palisades range, as a monoclinal ridge bordering the Hudson from Jersey City to Haverstraw, whose features on the river are not broken by a political boundary, but make a unit in natural scenery, and whose preservation demands the care and co operation of both States to prevent the work of destruction which is threatening alike the range in both New Jersey and New York.

ARTESIAN WELLS.

The records of artesian and deep-bored wells are given in Part III, of this Report, by Lewis Woolman. Many wells are reported from the southern part of the State in considerable detail; from the northern part of the State data have been furnished for this report of Mr. Woolman, by Messrs. P. H. and J. Conlan, Stotthoff Brothers, W. R. Osborne, Louis L. Tribus and Wm. Wallace Chrystie. The Geological Survey recognizes the courtesy and painstaking labor of these and other well-boring firms in the State who have so kindly given valuable information for this part of the Annual Report. Mr. Woolman has discussed the subject of water-bearing horizons and their place in the geological series, and the determination of these horizons is a valuable help to all who are about to put down wells in the southern part of the State. The section from Philadelphia to Atco (Plate III) illustrates the position of some of these water-bearing beds, and summarizes, in a graphic way, a great deal of information which has been collected by Mr. Woolman during the progress of his work for the Survey. The table of wells shown on this section, gives the references to the Annual Reports where their records are published. The section and accompanying text will be suggestive in the application to a large part of Southern New Jersey. A few well records from Philadelphia, Rock Hall, Md., and Old Point Comfort, Va., are included in this report, because of the confirmatory character of the geological order and of the position of the water-bearing beds.

In the northern part of the State, the reports of the wells at Madison and Chatham are notable for the thickness of the earthy beds of drift and the large flow of water above the surface. The sources appear to be coarse, gravelly beds in the terminal moraine.

The wells in the Red Sandstone belt, as here reported, show that there are water-bearing beds, but their position in the formation and the determination of any water horizons are not made out from the

data at hand. Further studies of the bored-well records from this geological formation of Triassic age may show the position of water-bearing, sandstone or shale beds, and enable us to determine the depth to which wells have to be bored to get water. The success of some of the well-borings in Jersey City is in sharp contrast with the great depth of other bores near them.

The record of a well in the gneissic rocks of New York is interesting and suggestive in the application to localities on such crystalline schists.

The report of Messrs. P. H. & J. Conlan, of wells bored by the firm in 1891, makes a valuable supplement to the records which they have given to the Survey. The thickness of the earthy beds on the Red Sandstone in Newark and vicinity and the large volume of water which these wells afford are remarkable.

REPORT ON WATER-SUPPLY FROM WELLS, BY C. C. VERMEULE.

The subject of artesian wells, as discussed in the reports by Mr. Woolman, has been restricted to the records of beds passed through, and to the determination of the geological position of the water-bearing beds, and largely in the southern part of the State. The importance of a wider range of discussion and the desirability of further studies of the questions which are embraced in the whole subject of underground water-supply, have been recognized and appreciated. The Report on Water Supply, published as Volume III of the Geological Survey Series of Reports, contained the results of the surveys and studies of the surface water-supply or that from streams. The underground supply is so intimately related to the surface supply that the question of wells may be considered as a part of the general subject of water-supply. Accordingly the discussion of water-supply from wells was included in the work of Mr. Vermeule. He has begun his studies on the subject, and has discussed some of the general questions of the conditions which are necessary to make flowing wells. In this preliminary report, introductory to further discussions of the subject, the source of all the underground water supply available for bored wells is clearly set forth as from the surface. The popular opinions about underground reservoirs and subterranean streams are often erroneous, and the statements made by Mr. Vermeule deserve careful attention in order to an accurate conception of

the fact that all the artesian wells draw their supply ultimately from the surface waters. The available amount of water from a given square mile is shown by a study of the tables on pages 150-159.

The conditions essential to flowing wells are given and with particular reference to the wells on the Atlantic coast or sea-shore of the State. Reference is made to the report of Prof. T. C. Chamberlin, published in 1885, in the Fifth Annual Report of the U. S. Geological Survey, where the conditions which produce flowing wells are discussed. Mr. Vermeule presents an important modification of these general conditions, and one which is applicable in explanation of the flowing wells of our sea-shore territory. The hydraulic grade-line, as an element in producing flowing wells, is illustrated in the case of wells on our coast and generally in the State.

The report includes a section on the rate of inflow of water through natural material surrounding the well, and tables giving the velocity through sands and gravels of varying size of grains and the relation of this rate of inflow to the maximum yield of some wells as examples.

One of the most important sections of this report is on the determination of the limits of the gathering-ground, as it shows the distance from which wells having a given capacity of flow draw from, or what is called the well-cone. The limits are larger than is generally stated, and the distances given indicate the probable interference of wells which are close together and drawing from the same depth. The effect of gang-wells at Merrick, on Long Island, in lowering the ground-water to the distance of a mile, is suggestive in its bearing upon the question of water-supply from gang-wells or well groups in New Jersey. The diversion of underground waters is likely to become as important as that of surface waters in relation to proprietorship. The interference of wells in their flow is already a fact at several localities in the State where they are near one another.

This report indicates the limits of the well-cone or gathering-ground in homogeneous strata, and it suggests the explanation of the phenomena of oscillations in the height of the water observed in some wells at the sea-side. The more or less pervious strata of the well-cone admit of a tidal force, which would not be possible were the impervious beds prolonged seaward.

The importance of having clear conceptions of the nature of artesian wells, and accurate knowledge of their sources of supply and the limits of their gathering-grounds makes this report of Mr. Vermeule

a valuable addition to the publications of the Survey. It is the most important paper on artesian wells which has appeared in these reports and deserves the careful study of those who are about to bore wells, and of all who are using the artesian-well system of water-supply.

TOPOGRAPHIC WORK.

The topographic surveys have been in charge of Mr. Vermeule, and he has had Peter D. Staats as assistant. Mr. Staats has been in the field throughout the season, making the surveys necessary to a revision of the topographic maps and to the new series of large-scale maps. He has given some time to a survey of the western border of the wooded belt of the southern part of the State. Local surveys of small forested areas also have been made for the report on forestry.

The necessity for a revision of the topographic maps, particularly in the more densely populated districts of the State, has been referred to in the Annual Reports. The topographic survey was begun in 1877 and completed in 1887. The field work was on projection sheets, having a scale of three inches to a mile, but the reduction to one-third or one inch to a mile was necessary on account of size and the number of sheets. A period ranging from eleven to twenty-one years has elapsed since the surveys were made. The rapid progress of the State has been marked by many changes, in the extension of city streets, new country roads, new steam railway lines, electric railways, new townships and municipalities and other changes of political boundaries. The revision for the new editions of the topographic maps has been mainly that of the railway lines. It has been impossible to do more, hence the new survey and revision for new maps and on a larger scale. There is need of maps on a larger scale by the geologist, for the accurate mapping of geological boundaries and for the exhibition of the several features of economic importance, as quarries, mines, clay banks, sand and gravel pits, marl beds, etc. They are wanted by the constructing engineer, also, for locating roads, railways, aqueducts, sewers and other works of public service.

It was decided to begin a field revision of the topographic survey and the publication of new series of maps. The scale adopted, 2,000 feet to one inch, is slightly less than that of the original projection sheets. The scheme of sheets is such that the number covering the State is large, but the work of revision in many of the country dis-

tracts will be slight. They cover seven minutes in latitude and thirteen in longitude, making sheets 21 x 30 inches inside the margins, and 25 x 35, outside measurement. As they meet edge to edge the joining of four sheets may be such as to make combined maps of related parts, as for example, the Jersey City, Hackensack, Newark and Paterson maps make a valuable and interesting suburban map; or Elizabeth, Plainfield, Woodbridge and New Brunswick sheets; or Camden, Woodbury, Mount Holly and Atsion, &c. The field work for five sheets, viz., the Newark, Jersey City, Paterson, Hackensack and Camden, has been done. They are in course of preparation for publication. The field work is being done by Mr. Staats and the draughting by J. R. Prince. The photo-lithographic work is by Julius Bien & Company.

The new maps will be sold, as are the old topographic atlas sheets, at a low rate—sufficient to cover the expenses of paper, printing and mailing or express carriage to the buyer. The surveys necessary for revision go slowly, and the publication, therefore, must go on at a moderate rate of progress, the suburban and more densely populated districts and where the changes have been greatest, taking precedence in the order of publication.

DRAINAGE.

An act to provide for the drainage of lands, approved March 8th, 1871, authorized the Board of Managers of the Geological Survey, "on the application of at least five owners of separate lots of land included in any tract of land in this State which is subject to overflow from freshets, or which is usually in a low, marshy, boggy or wet condition," to examine such tract and make surveys and adopt a system of drainage for the same. Under the general drainage law, as amended by supplementary legislation, salt marshes and lands flowed by tide water are included in the provisions of these acts.

The Passaic drainage work was referred to in the last Annual Report by George W. Howell, one of the commissioners appointed by the Supreme Court to execute the drainage in accordance with the provisions of the general plan of the Board of Managers. The report of Mr. Howell described the condition of the work and stated the needs of the commission to carry out faithfully the drainage plan. The want of the necessary funds to do the work has prevented further

progress, and nothing has been done since 1892 toward completing the drainage. The improvement in the financial world and the abundance of capital seeking investment have stimulated the commissioners, the land-owners and the friends of the drainage scheme to make further attempts to raise the money to finish the work. These efforts have so far failed and no progress has been made. The importance of the work in its relations to the lands in the upper Passaic valley subject to overflow, in the improvement of the quality of the water of the Passaic river at Little Falls, and in the betterment of the sanitary conditions of all this part of the State, calls for immediate attention on the part of not only the land-holders and residents of the valley, but of all who are interested in the promotion of the public health and the prosperity of the people of the State. It is not merely a local work or improvement—it bears the approval of a department of the State in its plan, and a State-appointed commission is charged with the execution of the plan. The work must be done. But this long delay is unfortunate in leaving thousands of acres of rich meadows to be wasted yearly by floods, in spreading malarial fevers all through the valley, and in fouling the Passaic river water with an enormous mass of decaying vegetable matter. It is piling up an interest account which must bear heavily upon these lands unless relief is had very soon. The State has given all the legislation which has been asked, and the courts have certified to the constitutionality of all the drainage laws which were effective in the case of the Pequest drainage, where the conditions were similar to those which prevail in this valley.

RECLAMATION OF THE HACKENSACK AND NEWARK MEADOWS.

The improvement of the tide-meadows along the Hackensack, and near Newark and Elizabeth, by means of banking with dikes and pumping out the water, has been referred to repeatedly in the Annual Reports of the Geological Survey. One of the leading objects of a visit to Holland and to the fen country in England by the late Dr. Cook, State Geologist, was to collect data bearing upon this question of the reclamation of wet lands and lands subject to tidal overflow. A full report on what was seen in Europe was given in the Annual Report for 1870.* In 1892† the question was again presented under

* Annual Report of the State Geologist for 1870, pp. 18-52.

† Annual Report of the State Geologist for 1892, pp. 331-353.

the heading, "Notes on the Reclamation of the Lowlands of the Netherlands," and the application to the tidal marsh-lands of the State of the Dutch methods of embankment was suggested as practicable, and the value of these lands, so near the metropolis, was urged as an argument for their reclamation. Short notes on the subject were given in the Annual Reports for 1893 and in 1895, and the importance of having more information and accurate data suggested in 1896 the reference of the whole question to the Topographer of the Survey. A survey was made of the meadows and a map published, accompanying the report of Mr. Vermeule that year.* In the last Annual Report the plan for reclamation works and the ultimate improvement by means of canals and broad dikes, with street and railway lines and dock fronts, were embodied in a second report by Mr. Vermeule.† These two reports, with the map of the meadows, have been distributed extensively in the northeastern or suburban district of the State and to parties interested in such works of improvement. The subject continues to attract attention and the plan of the report has been approved generally by those who have studied carefully the situation. The difficulties of intermunicipal agreement and their settlement are in the way of rapid progress in any general scheme taking in the whole of this district, and the solution appears to be in the direction of separate action by cities and other municipalities each improving the territory within its corporate limits. In this way the plan for the improvement of a tract of 4,000 acres of marsh within the limits of Newark will be considered and the work be begun at an early date. Jersey City has within its limits 2,086 acres of tide-marsh, and Elizabeth has 2,658 acres. The three cities have, therefore, about 8,700 acres of the 27,000 acres lying between Elizabeth and Hackensack. Conditions are also favorable to the reclamation of about 4,000 acres in Kearney township. The promptness which will attend the work of reclamation by districts is, perhaps, promising of an earlier general success than is to be looked for in a plan or scheme taking in the whole district. The objections on account of conflicting systems were stated in the last Annual Report as an argument for a single comprehensive plan of drainage. However, the prospects of action by the cities, whose limits include large areas of the meadows, indicate reclamation measures on a large scale and not necessarily inconsistent with the requirements of a general scheme.

* Annual Report of the State Geologist for 1896, pp. 287-309.

† Annual Report of the State Geologist for 1897, pp. 297-315.

Public opinion generally favors the reclamation of these Hackensack and Newark meadows, and the capabilities of the plans of improvement, as presented by Mr. Vermeule in his reports, are attracting attention on the part of capitalists and business men, who see in these tidal lands of our cities valuable sites for manufacturing industries and commercial activity. The economic argument, great as it is, falls behind the sanitary importance of reclaiming these lands, and saving them and the cities adjacent thereto from what ultimately must be their conditions of ill-drainage, bad sewerage and pestilential dumping-grounds. The enhanced value of the upland areas about them as residential property should not be left out of consideration.

FOREST SURVEYS.

An act of the legislature, approved May 1st, 1894, directed the State Geologist, with the assistance of an expert botanist, to make investigations of the forested lands of the State, and to prepare a report on the results of their investigations and surveys. Mr. Gifford Pinchot (now chief of the Division of Forestry, United States Department of Agriculture) was appointed as botanist. He has made his report, and, by direction of the Board of Managers, that report, entitled "Forest Fires and Wood Production in Southern New Jersey," is published as an Appendix to this Annual Report. It is valuable for its statistics of wood production under the conditions of repeated fires and of woodlands which have not been burned over. The result of fires in destroying the timber is shown by several illustrations of fire-scarred woodland, and by the tables of production per acre. The crop of wood is now scarcely one-sixth of what it should be if forest fires were prevented. Of merchantable lumber there is practically none produced. Some protective system against fires is necessary, and Mr. Pinchot presents a plan for fighting fires and affording protection.

So much has been written in a general way about forest fires and the losses due to their devastation that this report of Mr. Pinchot, fortified by its statistics of acres of woodland of original growth, of second growth, and of land repeatedly burned over, is exceedingly valuable in evidence of the great aggregate losses from forest fires, which now burn over nearly the whole of the pines belt of Southern

New Jersey. It is an important contribution to our knowledge of the forests of the State and their desolation by fires.

In the progress of the work in forestry, Prof. Arthur Hollick, of Columbia University, has continued his studies on the distribution of the tree species which occur in the State, and their relation to the geological formations. An abstract of his report, which he has prepared for the Survey, is here given :

J. C. Smock, State Geologist, Trenton, N. J. :

DEAR SIR—In my previous report of progress on the relation between geology and forestry, in New Jersey, an outline was given of the general principles upon which the investigation was based.

During the present year the investigations were continued along the same general lines, constantly keeping in view the theory that the geological formations, or what amounts to the same thing, the soil conditions, both mechanical and chemical, are the most powerful factors in determining the location and limitation of certain species of trees.

During the early part of the season considerable attention was paid to the northern part of the State. Careful explorations were made in the vicinity of Sparta and sections were traversed from Sparta to Waterloo, Waterloo to Allamuchy and along the Delaware river from the Water Gap to Bushkill.

The result of these explorations was to confirm my previous experience, that the most interesting region—the region containing the greatest number of facts in connection with the limitation of species, was to be found further south. Subsequent explorations were therefore made between the coast-line and the Delaware river, and one complete section of the State was traversed from Point Pleasant, through Lakewood, New Egypt and Mount Holly to Burlington. Shorter sections were also made, from Freehold to Red Bank and from Red Bank to Old Bridge. From the facts thus gathered I was enabled to divide the State theoretically into three zones of vegetation: the northern or deciduous, the southern or coniferous, and an intermediate one which I propose to call the “tension zone,” because it is there that the two floras meet or overlap, causing a constant state of tension in the struggle for advantage.

After recognizing this broad generalization, based on the distribution of the two great classes of our trees, attention was directed to cases of specific distribution within each zone, and several such were worked out with satisfactory results. These will be given in my final report, but one example may be given here in order to indicate the general scope of the work.

Pinus rigida Mill, the common Pitch pine, exists over hundreds of square miles in Burlington and Ocean counties, often to the exclusion of all other trees. It is the prevailing species throughout the pine barren region and is known outside the State from Florida to New Brunswick. Outside the coniferous zone, however, it occurs only as isolated groves or individuals, and if these are destroyed a deciduous growth generally replaces them, whereas within the coniferous zone, under similar conditions, they usually reproduce their kind. These facts at first seemed to indicate that the soil of the zone in which they are most abundant was the most favorable for them, but closer in-

vestigation showed that this was not the case. The groves and individuals growing further north were found to be, as a rule, larger and more vigorous than the average of the trees in the barrens, and the conclusion was finally reached that they exist in the latter region not by reason of the soil being more favorable for them, but by reason of its being less favorable for deciduous trees. The pines are therefore free from competition, and the natural inference is that they would exist to better advantage in other soils, but that the stronger and aggressive deciduous trees are able to occupy and hold these soils against them.

This conclusion naturally leads to the question how long this struggle for existence has been in operation and what the ultimate effect will be. The historical development of the existing flora is thus brought into the problem and this phase of the subject is being worked up from all the available data. The complete investigation will therefore include not only the facts of modern distribution but also the events which led up to them and a discussion of the indicated ultimate result.

Respectfully submitted,

Nov. 2, 1898.

ARTHUR HOLLICK.

The question of forest protection in New Jersey is really included in the greater problem of the State's water-supply and its conservation. New Jersey is not a lumber-producing State. The areas capable of producing merchantable lumber are of inconsiderable importance in extent. In the southern part of the State the clearings for agriculture are encroaching upon the pines belt; in the northern part the value of the land for residential purposes and for private parks and game preserves is too high for profitable forestry. And it is doubtful if wood can be produced at a profit over any large areas. These conditions of the forested territory of the State are against forest reservations solely as wood-producing or for purely forest culture. The relation of the forests in the Highlands to the stream-flow and water-supply of the cities in the northern part of the State was referred to in the Annual Report for 1895. Forest maps of the Highlands have been made for the Report on Forestry and the reservations are shown on these maps.

For the proper consideration of the forest problem in the southern part of the State, Mr. Vermeule has prepared a short report on the Pine Belt of that part of the State and its relation to the water supply of the towns and cities of Southern New Jersey. A small map of the State illustrates the report. The western limit of the forested belt is shown, as also that of the pine belt. The territory which seems available for farming purposes and for settlements, and which is probably destined to be cleared eventually, is indicated by the ruled

green parts of the map; that in solid color represents the unbroken forest, and these districts are suggested as reservations. Their value as great gathering-grounds for the unfailing supply of pure water to the many sea shore towns and settlements and the cities in the valley of the Delaware, is such as to make the reservation of these tracts for this use a question of public importance.

THE IRON-MINING INDUSTRY.

Mr. George E. Jenkins, of Dover, has prepared a report of his observations on the iron-mining industry and the iron mines of the State. All the mines which were reported in the last Annual Report have been worked more or less throughout the year. The works at Edison have added to the number of producing plants and to the total output, which exceeds slightly that for 1897. The statistics for a period of years appear on pages 239 and 240.

CLAYS AND CLAY-USING INDUSTRIES.

Mr. Jenkins has continued the work of collecting notes of the brick and clay industry and their statistics of production. The survey of the field indicates a large increase in output and a general resumption of work where last year plants were idle. The statistics show notable increases in common brick, pressed brick and in fire-brick. There is a large increase in the total amount of crude clays, moulding-sand and fire-sand. The increase in the total brick manufacture is nearly 25 per cent. over that for 1897. As the clay beds of the State are so situated on tidal and navigable waters as to afford cheap transportation to the metropolitan market of the country, and are practically inexhaustible, the brick-making industry of the State promises to continue to be a large one.

The collection of these notes in this survey of the brick manufacture and the other clay-using industries has been made to serve as a guide to a detailed survey and a report on the clays of the State and their uses in the arts.

CHEMICAL WORK.

The chemical work of the Survey has been done by Prof. Wm. S. Myers, of Rutgers College. The examinations are mainly in the

nature of partial analyses and assays to ascertain the nature of specimens submitted to the Survey for report. No complete analyses or exhaustive examinations of specimens are possible, inasmuch as the Survey has no laboratory, and the work is of necessity done by this special arrangement.

GEOLOGICAL ROOMS.

Since the last report of the Survey the mineralogical collection has been arranged, according to the system of Prof. Dana, in table-cases in the museum-room in the State House. This arrangement is the work of Mr. W. F. Ferrier, and, in part, of Professor A. H. Chester, of New Brunswick. Professor Chester had charge of the arrangement of the large specimens in the large table-case against the wall. The mineralogical exhibit of the State of New Jersey is such as to show the great variety of species which occur in the State, particularly of the zinc-mines district. The variety in the trappean minerals as found in the Bergen Hill rocks is notable. The new minerals found at Paterson are also worthy of note. The inferior nature of many of the specimens in this mineralogical collection, and the gaps in the localities which are known as the source of good minerals, suggest the addition of better specimens and the representation of other localities in order to a proper exhibition of the mineralogical wealth of the State.

The collections have been enlarged during the year by additions of valuable series of building bricks and other products of clay-working industries. The want of room for the proper exhibition of materials of this kind is a serious drawback to the growth of the collections, and prevents the proper arrangement of the products of the other industrial arts. The value of an industrial museum at the State capital, where the collections of natural products may be seen by the side of the manufactured products, suggests the necessity of provision for better exhibition.

PUBLICATIONS.

The publications of the year have been the Annual Report for 1897 and Volume IV of the "Final Report" series. This volume on the physical geography of New Jersey is accompanied by a relief map of the State on a scale of three miles to an inch. The volume has been

widely distributed to public libraries and to scientists in the State and throughout the country. The distribution to the public schools is in progress and is nearly done. The placing of this map in the public schools is regarded as an important step in the provision for the proper study, not only of the geography of the State but of physical geography, as teaching the more characteristic features of the earth's surface. The educational value of helps of this nature is recognized by teachers generally and the results of the surveys are in this way made public to the highest advantage.

STAFF OF THE SURVEY.

PROF. ROLLIN D. SALISBURY, Geologist, is in charge of the survey of the Surface Formations. He is assisted by G. N. KNAPP.

HENRY BARNARD KÜMMEL, of Lewis Institute, Chicago, has continued the survey of the Red Sandstone rocks of the Newark system.

CORNELIUS C. VERMEULE, Topographer, has had charge of the Topographic Surveys and of the Studies of Water-Supply. PETER D. STAATS is field assistant.

IRVING STRONG UPSON, at New Brunswick, is the disbursing officer of the Survey and has charge of the sales of maps.

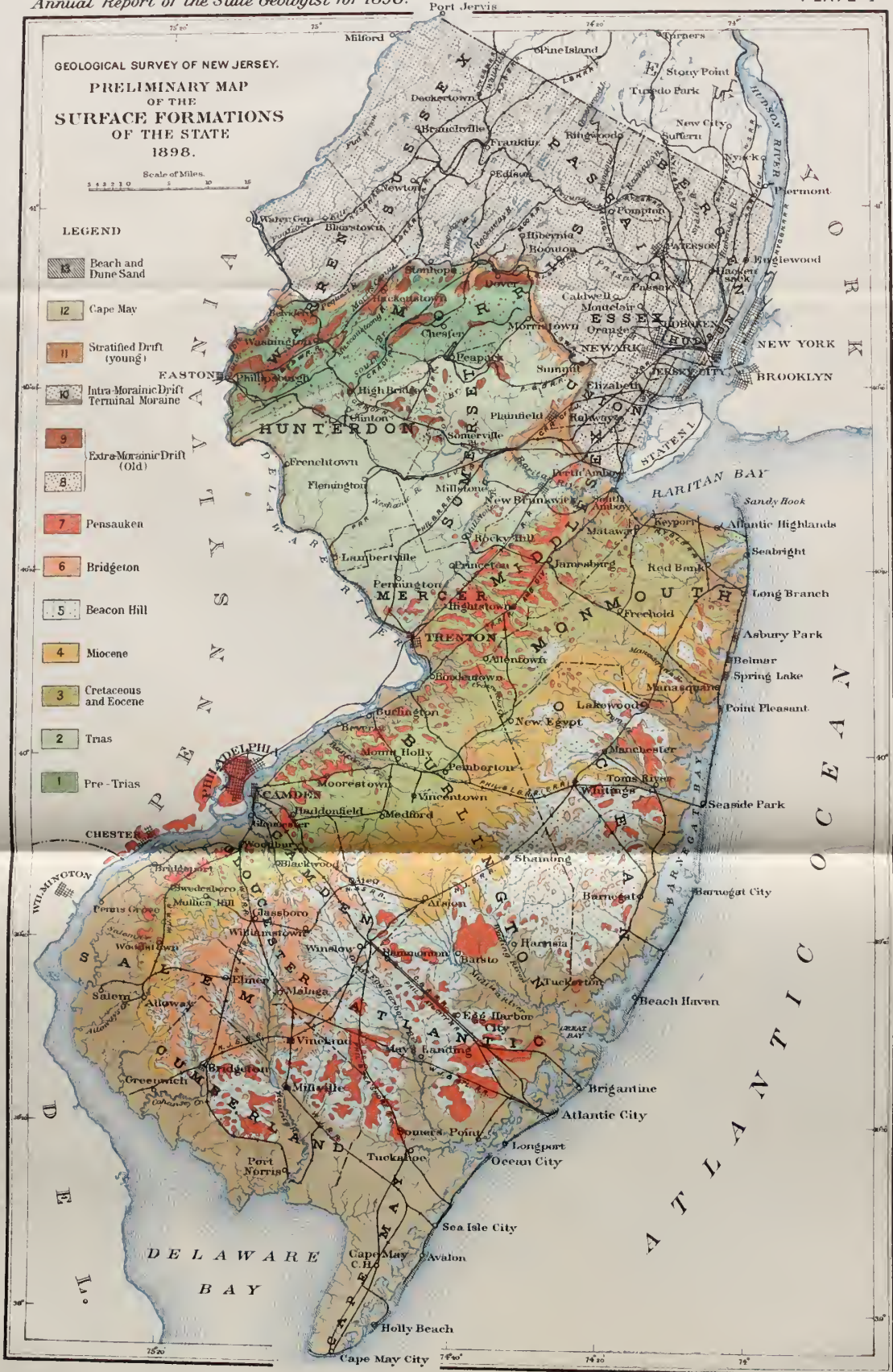
HATFIELD SMITH is general assistant in the geological rooms, Trenton.

PART I.

Report on Surface Geology

BY

ROLLIN D. SALISBURY.





The Soils of New Jersey and Their Relation to the Geological Formations Which Underlie Them.

The term soil is used in different senses by different classes of people in the same region, and by the same class of people in different regions. Among those engaged in agricultural pursuits the term soil is usually understood to mean the uppermost portion of the loose material which overlies the solid rock. According to this usage the soil extends from the surface down a few inches, rarely as much as two or three feet. Below it lies the subsoil, into which the roots of all but the smaller plants penetrate. The term subsoil is a somewhat flexible one, and is often applied to all that unconsolidated material beneath the soil which roots penetrate. This is the sense in which the term is here used. In many places roots penetrate the rock beneath loose material, but rock so penetrated is not usually regarded as a part of the subsoil. The plane of division between subsoil and rock is often an indefinite one.

The character of the subsoil is often as important as that of the soil. If, for example, the subsoil be a body of dense clay, it does not allow the ready passage of water through it. The waters sinking beneath the surface are likely to sink down to the clayey layer and stand there. If the top of the clayey substratum is very near the surface, and if rainfall is plentiful, this is injurious to the plant life. Under other conditions it may be advantageous. In regions of plentiful moisture a loose, porous subsoil which affords ready under-drainage, overlain by a loamy soil, affords a good combination.

Several considerations determine the value of a soil. Chief among them are the physical and chemical constitution of the soil, and its disposition.

The influence of physical constitution is easily understood. A soil may be made up of constituents which are too coarse or too fine for the best results. Thus a soil, a large proportion of which is made up of gravel-stones, is, other things being equal, much less productive than a soil made up of loam. In general, the presence of stones, large or small, is harmful, though this is not true in every case. A clayey soil, that is, a soil made up of extremely small particles, is said to be "heavy." The finer the particles the "heavier" (more compact) the clay. Soils made up of extremely fine particles are, on account of their compactness hard to work. Furthermore, a heavy clay soil on a flat surface, will in wet seasons cause water to stand on it to a harmful extent. The same soil will bake in dry weather. It also tends to prevent the ready circulation of air in the soil, a process which is necessary for the best results. Such a soil would be none the worse for the admixture of small fragments of rock, as they would help to make it more pervious to air and water.

On the whole, the best soil is one which is neither clayey nor stony. The grade of coarseness or fineness which is most desirable depends somewhat upon the amount of moisture, but, in general, soils of loamy nature are better than those which are heavier or lighter. Loam may be made either of particles intermediate in size between the particles of clay and grains of sand, or it may be made of a mixture of clay particles and sand grains. Loamy soils will stand both drought and excessive moisture better than those of coarser or finer texture. They do not prevent the entrance of surface waters, and so do not ordinarily cause water to stand on the surface; they allow adequate circulation of air in the soil; they do not bake after being wet, and they are sufficiently fine to allow capillary moisture to rise from beneath when the surface becomes dry. In the first three particulars the loamy soil is superior to the clayey, and in the last to soils of more open texture.

Of late years it has been the fashion to magnify the importance of the physical constitution of the soil, and minimize the importance of its chemical composition. According to this view, soil is primarily a supplier of moisture to growing vegetation, and is good or poor according as it performs this work satisfactorily. But since all vegetation makes use of more or less mineral matter,

and since many cultivated plants do not thrive except certain sorts of mineral matter are furnished them, it would appear that the chemical constitution of the soil and subsoil is an element of some importance, since it is largely from them that the mineral matter is brought into solution and so made available for vegetation. In general, the mineral substances which plants make most use of are among the more soluble constituents of soil and rock. A soil good for any particular sort of plant should contain the mineral matters which that particular plant needs. Thus plants which need lime carbonate thrive best in a soil which contains that substance. In so far as the water used by plants ascends through the subsoil it may bring up mineral matters from greater depths.

One of the elements of the value of soils therefore depends upon the mineral matters which they contain. Usually it is the minor constituents of a soil which are of special importance, for the main constituents, like the main constituents of the air, seem to play relatively unimportant roles. A soil which has various soluble mineral matters needed by various plants is capable of a greater range of possibilities than soils of more restricted composition.

Another consideration which determines the value of soils is their disposition. The physical and chemical constitution of soils may be such as to render them fertile; but if they be not properly disposed, their constitution avails little. Thus, if they are on slopes which are too steep for cultivation, they are worthless for agricultural purposes. Level surfaces and surfaces of no more than moderate slope, therefore, are the only ones which are available for agricultural purposes.

The popular impression that the value of soil may be judged by its color is not well founded. In the northern part of the Mississippi basin black soils are regarded as most desirable, but in some other regions black soils are unknown, though soils equally fertile are present. In New Jersey, for example, there are no soils more fertile than those of the marl belt, where the soils are not usually black. Much of the Red Sand belt of Monmouth county is exceedingly productive, though the soils are strikingly red. No equally great area of the State is under such general cultivation as that of the Triassic formation, where the soil is predominantly and strikingly red.

THE SOILS OF NORTHERN NEW JERSEY.

The soils of this part of the State will be spoken of in several sections, corresponding in a general way with the several geological formations or groups of formations.

THE AREAS OF PALEOZOIC FORMATIONS.

The Paleozoic formations appear at the surface chiefly in the northwestern part of the State west of the Highlands. The larger part of this area was covered by the ice of the last glacial epoch, and essentially all by the ice of an earlier epoch. The terminal moraine is, however, a convenient line of division between an area to the north where the soils are principally controlled by the drift, and an area to the south where they are chiefly the result of local rock decay. In both areas the soils vary with the underlying rock, but the relation is much closer south of the moraine than north of it.

West of the Kittatinny Mountain.—The area west of the Kittatinny valley was all glaciated. Its best lands lie along the Delaware river, and in the Flatbrook and Mill brook valleys, on deposits of stratified drift. Along the Delaware this drift is disposed in the form of terraces, below which is the alluvial plain of recent origin. The soil of the alluvial plain is generally a sandy loam, which is cultivated easily and with good results. It is sometimes unduly sandy, being locally so loose as to be blown by the wind.

The lower terraces of the Delaware, like the alluvial plain, are almost uniformly covered by a greater or less thickness of loam. The highest terrace is composed to a much larger extent of gravel, or at any rate the gravel of which it is composed is much less deeply covered by fine material. The soil of this terrace frequently abounds in cobble-stones and even small bowlders, and is therefore less well adapted to cultivation than that of the lower levels.

The soils in the Flatbrook and Mill brook valleys are comparable to those of the Delaware, but less change has taken

place in these valleys since the deposition of the drift, and much of the deposits corresponding to the highest terrace of the Delaware still remains. Soils corresponding to the sandy loams of the alluvial plains and lower terraces of the Delaware are not so abundantly represented, and the soils have, on the whole, more likeness to those of the upper terraces of the Delaware. They are sometimes too sandy or gravelly to be productive of the best results, though more often they are fairly productive.

On the ridges between the valleys the surface is covered with glacial drift, which in this region is often so stony as not to afford a soil which is easily cultivated, and often so thin as not to give a sufficient subsoil. In much of this region, too, the slopes are too steep for tillage, and as a result considerable areas remain uncultivated. Locally, however, the drift is sufficiently thick, sufficiently free from stone, and so disposed as to have invited cultivation, and the results have been satisfactory.

In this region the soil varies with the till, which changes its character as the underlying formation changes. The correspondence between the till and the underlying soil is more conspicuous where the drift is thin than where it is thick. The most significant of these changes, so far as concerns the soil, is the increase in calcareous matter in the subsoil where the underlying rock is limestone.

The Kittatinny Mountain.—Like the area to the west, the Kittatinny mountain was completely covered by the ice of the last glacial epoch, but the drift which it left is generally thin and stony. Over considerable portions of the mountain bowlders from the Oneida and Medina formations are so abundant as to effectually forbid all attempts at cultivation save at great expense and labor. Not a few clearings once made have been abandoned. The drift is so thin that the bed-rock frequently outcrops, and where timber has been allowed to grow without molestation, it is often but stunted. The western slope of the mountain is much more generally covered with drift and soil than its crest and eastern slope, but even here a large portion of the slope is still in forest, and should be allowed to remain so permanently.

The color of the surface material on the Oneida formation is often much lighter than that on the Medina, illustrating the promptness with which the underlying rock makes itself felt in the drift, and so in the soil.

The Kittatinny Valley.—The Kittatinny valley affords many more or less distinct types of soil. The bed-rock of the valley, consisting of Hudson river shale and Trenton limestone, is covered by a mantle of glacial drift of varying constitution, texture and thickness. The drift is partly stratified and partly unstratified (till). The stratified deposits give rise to several types of soils, according as the surface-layers of the drifts are gravelly, sandy or clayey. The soils of the till vary physically in the number and size of the bowlders at the surface, and chemically with the nature of the underlying rock, especially where the drift is thin.

Stratified Drift Soils.—The stratified drift occurs principally in the subordinate valleys of the great valley. These areas are almost wholly under cultivation, and not infrequently the limits of the stratified drift are coincident with the areas of cultivation. Examples of this are seen in the region southwest of Newton.

The various types of soil to which the stratified drift has given rise are often intimately associated, are indeed sometimes found within the limits of a single field. With the stones of the gravelly soils there is always more or less sand and clay which serves as a matrix, filling in the spaces between the stones. Carbonate of lime is commonly abundant in the gravelly subsoil and sometimes in the soil itself. The sandy soils of this region, contradictory as it may seem, are as a rule looser and drier than the gravelly soils. This is because they are freer from fine clayey matter. They have in general less carbonate of lime than the coarser drift which contains many pebbles of limestone.

In many places the upper part of the stratified drift is a heavy, clayey soil, which does not suggest the real nature of the gravelly drift which it covers. Such soils are most likely to occur where the gravel beneath is chiefly of shale. Such soils are rarely highly calcareous. Their under-drainage is good, and they do not suffer from ordinary droughts. Types of clayey soils over stratified gravelly drift are to be found in the valley of Paulinskill, Clove and Pequest rivers, Papakating and Little Papakating creeks, and at some other points.

At a few points there are clay terraces, giving rise to distinctly clayey soils. A low terrace of this sort occurs in the valley of Papakating creek, in the vicinity of Roy's station.

Till Soils.—In the till areas of the Kittatinny valley the soil is usually a stony clay, within and upon which pebbles and bowlders of all sizes are likely to occur. For two or three miles east of Kittatinny mountain the surface is so thickly bowlder-strewn, and stones are so abundant in the soil, that much of the land is not cultivated, and is in pasture or timber. Farther from the mountain the bowlders become less abundant, and the soil yields itself more readily to clearing and cultivation. These soils are rarely highly calcareous.

The availability of the till soils of the valley is limited by two things: (1) It is sometimes too thin, and (2) the slopes are locally too steep for tillage. These two things generally go together, the till being thin on the steep slopes and narrow crests. A large proportion of the Kittatinny valley is not affected by either of these restrictions.

Where the drift is thin, as in much of the Kittatinny valley, the underlying rock has contributed largely to the soil. In the region underlain by the Hudson river shale many knobs and hills of rock were left essentially bare by the ice. The disintegration of the shale under the combined action of the frost and plow has produced a thin soil, made up chiefly of the broken fragments of the shale, which is sufficiently fertile to warrant cultivation. There are, of course, all gradations between the stony clay soil of the thick till, and the thin shale soil on the knolls, depending upon the amount of foreign material which has been mixed with the broken shale. Both types may often occur within the limits of a single field. Owing to the thinness of shale soils their vegetation is easily injured by drought.

Limestone Soil.—Where the drift is thin and limestone the underlying rock, the soil and subsoil have largely arisen from the decomposition of the rock. Limestone disintegrates mainly by solution, less actively by mechanical means. Consequently the soluble part—chiefly lime carbonate—is leached out, and only the insoluble residue, generally a reddish or brown or yellow clay, remains. This is washed down into the depressions between the elevations, where the rock is most commonly exposed. Consequently, in the limestone belts, where the rock is not covered by drift, the soil is thin, and there are many rock knolls and ledges, separated by depressions where the soil and

subsoil are thick. The soils, derived from the limestone by decomposition, are not calcareous and usually not stony. Owing to the frequent outcrops of rock, the thinness of the soil and its patchy character, there are many uncultivated areas in the limestone belt. Sharp contrasts are often seen, where limestone knolls, essentially free from soil, rise abruptly above the plains of stratified drift.

Humus Soils.—Many extensive swamp or meadow areas in Sussex and Warren counties have been partially or completely drained. These areas have a rich, black soil containing much vegetable matter in a state of decay, and are among the most fertile soils in the State. When first broken, such soils are likely to be heavy and "sour," but with drainage and exposure to air, and after such admixture of earthy matter as results from cultivation, these soils become workable and often extremely productive. The Pequest and the Wallkill meadows are examples of large areas of this sort, but there are scores of smaller areas of the same nature scattered through the region. Some of them have been drained, while others are still unused.

Some of the swamp soils contain abundant shells, which contribute to their fertility. The shells are from snails which lived in the lakes or ponds, the last stages of which the swamps represent. As the ponds or lakes were drained or filled by sediments, vegetation grew out over the former bottom, so that the accumulated vegetable matter now lies above the marly deposits of an earlier time.

Alluvial Soils.—Along the principal streams in the great valley there are alluvial soils in wide or narrow belts. While the larger part of such soil is of mineral matter, there is usually a considerable amount of organic matter mixed with the silt, and the alluvial soils often closely simulate the swamp soils mentioned above. Examples of alluvial soils grading into vegetable loam soils are found along the Wallkill.

AREA OF THE CRYSTALLINE SCHISTS.

The area of the crystalline schists is, so far as its soil is concerned, divisible into two more or less distinct provinces, that covered by the glacial drift, and that south of it. Though the

drift is not limited by the terminal moraine, the amount south of it is small.

South of the moraine the soils and subsoils have arisen from the decay of the rock. Since the decay of the schists gives rise to a soil which is good, both physically and chemically, it follows that the controlling consideration in this region is the topography of the surface. Where the surface is even or its angle of slope low, the soil is deep, loamy and easily cultivated. Where the angle of slope is high, the fine material of the soil has been washed away, leaving the coarser portion behind. The result is that in such situations the soil is often stony and has been cleared to a slight extent only. In general, the areas of gentle slope are cultivated, while those of steep slopes are wisely left in timber. Considerable areas of cultivated land having the soil normal to this area are to be found in the vicinity of Mendham and Hackettstown. These soils have the merit of not eroding readily, and washes are not especially troublesome, a point greatly in their favor in view of the slopes at which they occur.

Within the general area of the Highlands outside the moraine there are considerable belts of limestone and shale. Where these formations are the underlying rock, there are now valleys, for these formations have resisted erosion less successfully than the schists. In these valleys, the soil is partly alluvial, though it has also come in part from the decomposition of the limestone and shale beneath. In this category belong the Pohatcong and Musconetcong valleys, which are among the most fertile tracts in the State. The soils in these valleys are made up of a mixture of the product of limestone decomposition, loam washed down from the bordering mountains of crystalline schists, early glacial drift, and to a slight extent of stratified drift of the last glacial epoch, carried out from the ice by the waters which came from its melting.

Certain Highland valleys outside the moraine, such as that of the South Branch of the Raritan, contain considerable deposits of stratified drift. The topographic position of such deposits favors their utilization, and the soils are often good. Sometimes, however, they are too loose and porous for the best results.

North of the terminal moraine of the last ice epoch the soils of the Highland area are drift soils. Since the drift of this region is composed largely of material derived from the crystalline schists themselves, the soils are not altogether unlike those of the Highland area south of the moraine. Nevertheless, the difference is greater than might be inferred from the preceding statement, for the soil, and especially the subsoil, here contain much more material which is not thoroughly decomposed, as well as some admixture of mineral matter from other formations. On the broader and flatter areas the drift is more stony than the residuary products in like situations south of the moraine. Physically, therefore, the soils and subsoils of the Highlands were not improved by glaciation. Over much of the area, indeed, cultivation has been prevented by the abundance of the boulders. The drift, and, therefore, the drift soils, are more irregularly disposed than the residuary soils south of the moraine. This affects the value of the land only where soil is absent or too thin to be fruitful.

In general the ice had too little force in this region to greatly modify the topography of the underlying rock, and the slopes which were steep before glaciation remained so after the ice departed.

In the valleys of the Highlands, as elsewhere, there is much stratified drift, and this is much more generally cultivated than the till-covered areas. The slopes of the areas of stratified drift are usually low; in many places they are essentially flat. Their soils and subsoils are usually not too stony, so that both their physical constitution and their position favor their utilization. Though they are locally too loose and gravelly, the limits of cultivation are often one with the limits of stratified drift.

In the areas of Paleozoic rock in the midst of the Highlands, topography is the controlling element, so far as utilization of the soils is concerned. Bearfort, Kanouse, Green Pond and Copperas mountains are too steep and too bare of soil to be cultivated, but the lower lands about them, underlain by shale, are to some extent available for agricultural purposes.

THE TRIASSIC AREA.

So far as soils are concerned, the Triassic area of the State is divisible into several more or less distinct portions. There is, to the northeast, a large area covered by drift, which is distinct from the larger area to the southwest, which the ice of the last glacial epoch did not reach. Within each of these two main divisions there are sedimentary rocks and igneous (trap) rocks, which give rise to soils which are essentially different. Furthermore, the character of the sedimentary beds varies from point to point, being shale at some points and conglomerate at others, with all intermediate gradations.

The Glaciated Area.—Within the glaciated area of the Triassic formations the soils are nearly everywhere determined by the drift, but since the principal constituents of the drift throughout most of the area were derived from the Triassic formations themselves, the chemical character of the soil and subsoil is similar to that which would have existed in the absence of the drift. This is especially true on the sedimentary part of the series, since the disintegration of the shales and sandstones is physical rather than chemical. On the other hand, there is everywhere some admixture of materials from other sources. Physically, too, the drift soils over the sedimentary beds of the Trias are more like the residuary soils than in some other regions. The underlying formations in this area are so soft that they did not yield many boulders to the ice. Boulders from other formations are locally abundant in the till, but there are few areas where tillage is prevented for this reason. In general, too, the slopes are not so steep but that the soil can be utilized.

In general, the drift has much greater depth on the sedimentary part of the series than on the trap. In the areas covered by till (unstratified drift) the soil is on the whole disposed to be clayey. This is especially true of the lower lands, where the underlying rock is soft shale, but less true of the higher lands where the underlying rock is sandstone.

Where the drift is stratified, and this is true to a large extent in the valleys, it is sometimes too sandy or gravelly to be of the best quality, and there are not a few patches, once cleared, where cultivation has been abandoned. The aggregate area of such

patches is, however, not great. There are some areas which are ill-drained; many of them would afford an excellent soil. In this category belong many small areas and some large ones such as the meadows of the Passaic basin.

Contrary to the condition of things in the area of Paleozoic formations, the till areas here are more generally under cultivation than the areas of stratified drift. This is because of the greater availability of the former, rather than because of the poorer quality of the latter.

The trap ridges are in somewhat sharp contrast with the area of sedimentary rocks. In general they have much less covering of loose material; are, indeed, in many places essentially bare. In the second place, their slopes are often so steep that cultivation would be prevented, even were abundant soil and subsoil present. As a result, the trap ridges within the glaciated area are for the most part timbered, though their lower and gentler slopes, where there is more drift, are frequently cultivated. The soils of the ridges, where cultivable, show a considerable admixture of material from other formations, especially from the shale.

The Unglaciaded Area.—The several divisions* of the Triassic series give rise to greater difference of soil in the unglaciaded than in the glaciated area. The divisions now recognized are three, viz., the Stockton, the Lockatong and the Brunswick.

In the area underlain by the *Stockton beds*,† from Trenton and Wilburtha to Princeton and beyond, the character of the soil is chiefly determined by the covering of younger formations which overlie the Triassic beds, but the higher portion of the area where these beds occur have soils which have resulted from their own decomposition.

In the narrow area near Hopewell, along the southeastern face of the Sourland Mountain plateau, the soil is somewhat sandy and generally strewn with angular weathered slabs of the harder layers. The name Peach Ridge, which in years past was applied to this belt, is indicative of the agricultural use to which the soil was formerly put. Now, however, the term is not particularly appropriate. In the area northeast of Stockton the soil partakes of the nature of the rock beneath, being rather loose, sandy and

* Kummel. Annual Report of the State Geologist for 1896 and 1897. The following notes are taken in considerable part from Dr. Kummel's report.

† See map. Annual Report cited.

often pebbly. Slabs of sandstone and conglomerate strew the surface in great abundance. Both in color (mostly grey) and texture, the soil is in marked contrast with that of the adjoining regions, which is a red or yellow clay.

The *Lockatong* beds give rise to a rather heavy clay soil. The surface is often strewn with slabs of argillite and flagstone, and on the slopes outcrops of rock are of frequent occurrence. Except in places favorable for the accumulation of the soil from higher slopes, the depth of soil and subsoil are generally less than five or six feet. On the Hunterdon plateau, the soil and subsoil are often wet and heavy. This is due in great part to the poor drainage of the region, and the comparative impenetrability of the underlying rock. By tiling, the quality of the soil has been greatly improved. Since the *Lockatong* beds are resistant, while the associated *Brunswick* beds are not, the former now constitute ridges and their slopes are often too steep to have retained much soil.

The *Brunswick shale* disintegrates easily into a red clay, containing minute bits of rock and but few large fragments. Occasionally a harder layer yields a few weathered slabs. Where the rock is more of a sandstone the soil to which it gives rise approaches a sandy loam, although in most of the areas where this is its nature, there has been an admixture of foreign material.

In spite of the rapid disintegration of the shale and its gentle slopes, the soil is thin. This is due to the fact that the residuary product is so fine that it is readily washed and blown away, even from the gentle slopes. Since transportation has so nearly kept pace with disintegration, the shale is not covered by so thick a coating of residuary material as is the quartzite conglomerate, a local phase of the *Brunswick* beds. Owing to the thinness of the soil, which is often hardly more than broken rock, it is readily exhausted. In dry seasons crops are likely to suffer. Nevertheless, the ease with which this soil is worked, its favorable topography and good drainage, have caused it to be generally utilized, and no equal area of the State is so generally under the plow.

The drainage of parts of the *Brunswick shale* area, especially the area in the upper basin of the Passaic, was seriously interfered with by the deposition of the drift. Here there is a large

area, partially covered by drift carried by water beyond the ice, which is ill-drained and at present not productive. With proper drainage the soil and subsoil would be found to be of excellent quality. This area is a part of the bottom of the extinct Lake Passaic.

The areas of the quartzite conglomerate of the Triassic system uniformly attain greater elevation than the adjoining shale areas, though not altogether because the conglomerates are more resistant than the shales. Indeed, the depth of the soil and subsoil is much greater on the conglomerate than on the shale, and outcrops of rock are practically wanting save in the bluffs along the Delaware. The explanation of the greater thickness of disintegrated material on the conglomerate, and also of the greater height of these areas, is as follows:

When the shale disintegrates, as already indicated, the particles are so fine that they are readily washed down even the gentle slopes which prevail in the shale areas. The soil, therefore, is removed almost as soon as formed, and the rock is continually exposed to the attacks of the weather. The disintegration of the conglomerates, on the contrary, gives rise to a stony clay, containing cobbles up to eight and even twelve inches in diameter. The finest material—the sandy and clayey matrix—was at first readily washed down the steep slopes, leaving behind the quartzite pebbles and cobbles, which now form a protective covering and prevent further denudation. The disintegration of the conglomerate goes on beneath this covering, more slowly as the residuary layer becomes thicker, but at the same time transportation is checked by the accumulation of the larger fragments on the surface. Since these contain little or no soluble material, and can be reduced in size only as they are broken by changes in temperature, the denudation of these areas has been very slow. They form hills rising several hundred feet above the red shale areas. The soils which they afford are not the best, though they are used to advantage for a few crops, especially fruit.

The Soils of the Trap Ridges.—In general the soils of the trap ridges south of the moraine are thin and composed of stony clay. Over considerable parts of the ridges the slopes are too steep to have allowed much soil to accumulate, and forests have been allowed to remain. On the tops, where they are wide, the

soil and subsoil have sufficient depth for cultivation, but the soil is often so stony and its quality otherwise so uninviting that much of it has not been cleared. Where the surface assumes a plateau-like character, as on parts of Sourland mountain, the drainage is poor. On the whole, therefore, the trap areas are not attractive regions for agricultural pursuits. Nevertheless, there are not a few areas, usually small, where these unfavorable conditions are not present, and where the cultivation of the trap soils has proved profitable.

At the bases of the trap ridges there are often heavy accumulations of earthy matter which has been washed down from the slopes above. Such soils, favorable as their situation might seem, are generally not of the best quality. They are sometimes stony, usually too heavy, and, situated as they are, are too abundantly supplied with moisture, which seeps out from the bases of the adjacent ridges. Such soils are usually cold and wet, better adapted to timber growth than to cultivation. This type of soil is well illustrated along the base of First mountain between Bound Brook, Somerville and Pluckamin.

THE SOILS OF SOUTHERN NEW JERSEY.*

Since some of the formations of the southern part of the State have been but recently differentiated, their distribution is less generally known than that of the formations of the northern part of the State, and the accompanying map, reproduced from the annual report of 1897, will be helpful in defining their position. It will be appreciated that a map on such a scale, 15 miles to the inch, admits of little detail. The soils of the several formations will be referred to in the inverse order of their age.

SOILS OF THE CAPE MAY FORMATION.

The youngest formation of this part of the State is the Cape May formation. As will be seen from the accompanying map, it forms a narrow belt about the State from Trenton, via Cape May,

*The following account of the soil of Southern New Jersey is based on the work of Mr. Knapp.

to Raritan bay. The belt is widest in the southern part of the State, and often extends considerable distances up the valleys. The glacial gravel of the Delaware valley, at Trenton, is here included with the Cape May formation.

The Cape May formation in the Delaware valley originated by a submergence which drowned the main river as far north as Trenton, and at the same time the lower parts of its tributaries. In the estuaries thus formed there were deposited such soils, sands and gravels as were brought down by the streams which were not drowned by the submergence. As a result of this deposition, and of the erosion which followed the uplift of the submerged areas, there are now terraces of gravel, sand and loam along many of the tributaries to the Delaware.

Along the Delaware River.—At Trenton the broad plain is made up of sand and gravel, through which are numerous beds and seams of brown loam. The soil over this plain is, in general, fertile loam, but along its eastern margin, one and one-half to three miles back from the Delaware, the soil is more sandy, often so loose that the winds of late fall and early spring readily blow it about in fields that have been left bare of vegetation. Beneath the soil there is generally a layer of brown loam, one to four feet in thickness. This serves as a moderately retentive subsoil, while the loose gravel and sand below insure ready under-drainage.

Along Crosswick's and Doctor's creeks, and extending four to six miles from the Delaware, there are low terraces of this formation. The gravel and sand making the body of the terraces is covered by one to three feet of loam, which constitutes a fertile soil and upper subsoil. With increasing distance from the Delaware the terraces become relatively narrow, and are covered with light loam well suited to truck farming. These soils of the terraces are often in contrast with those of the higher lands.

In the lower parts of these tributary valleys, where they open out into the Delaware, the terraces are as high as the inter-stream areas, and the loam that overlies the terraces also spreads over the low divides, mantling other formations. The broad loam-mantled flats north and northeast of Yardville, and the loam and clay-loam flats between Yardville and Bordentown at the 60-foot level, are examples.

The lower courses of the tributaries to the Delaware farther south have gravel and sand terraces mantled by one to four feet of brown loam. This is so clayey as to be used at Kinkora and Bridgeborough for brick. Farther up the tributary valleys, back from the Delaware, the soil of the terraces differs but little from that of the adjacent uplands.

Between Florence and Camden there are many variations in the soil of the lowlands underlain by the Cape May formation. In general the surface is overspread by clay-loam, beneath which there is sand and some gravel. Subsequent to the deposition of the Cape May formation, stream erosion cut through the clay-loam at the surface and into the sand beneath. The sands thus exposed have been blown about by the winds, often up over the loam-capped remnants of the earlier surface, so that the loam and clay-loam which was originally at the surface has become the subsoil, while the originally subjacent sands have become the soil. This soil is well adapted to truck farming and peach growing.

From Camden southwest to Bridgeport the Cape May formation is very thin, except in the immediate vicinity of the tributary valleys. The soil of the Delaware lowland, here two to four miles wide, is therefore often influenced by the underlying Cretaceous formation. Where this is the case it is clayey in some places and sandy in others, varying with the character of the underlying beds. Along the streams tributary to the Delaware in this section, low and ill-defined terraces of gravel and sand are found, often running back several miles from the Delaware. They have a light, sandy loam soil, often better suited to truck growing than the adjacent uplands.

From Bridgeport to Salem the sands and gravels of the formation constitute a broad lowland bordering the Delaware. About Salem a considerable area (about sixteen square miles) of this lowland is covered by a very persistent bed of heavy loam one to three feet thick, which gives a strong soil and subsoil. Beneath it is the loose sand and gravel, insuring the ready escape of excessive water. The soil is here rather heavy for truck farming and is used instead for general crops.

North of Salem the relations are similar to those of the Salem plain, but the loam bed, not so persistent originally, has locally

been so deeply buried by wind-blown sand that it no longer influences the soil. Hence the soil here lacks uniformity, varying from worthless wind-blown sands, through good truck soils to heavy clay-loam. Much of the land here, too, lies too low—less than ten feet above tide—either for ready surface-drainage or for under-drainage, and hence often suffers from excess of water.

From Alloway creek to Cohansey creek the Cape May formation constitutes a broad lowland next the bay or river ; but about half of it, as it appears on the map, is salt marsh, and unavailable for cultivation, though much of it is used as salt-marsh meadow. From Salem north, along Salem creek, several square miles of these tide marshes have made excellent land. In general their soils are heavy clay loams, valuable especially for heavy crops.

The soil of that part of the lowland between Alloway and Cohansey creeks which is above tidal influence is most variable. Some portions lie too low to furnish good drainage, while others are so sandy that, either as a result of careless tillage or of their natural unmanageability, the winds have rendered them nearly worthless. Still other portions furnish a loamy soil of good quality.

Along Delaware Bay.—Between Cohansey creek and Maurice river at least two-thirds of the area represented on the map as underlain by the Cape May formation is tide-marsh or fresh-water swamp, at present not available for tillage. The remaining portion consists of extremely irregular patches and long, narrow necks of land along the inter-stream areas, much of which is too sandy to be tilled with profit. There are, however, limited areas of good soil within this area, as, for example, a belt one to two miles wide immediately south of Cohansey creek, and west from Fairton.

The Cape May formation, as developed in Maurice river valley, below Millville, constitutes low terraces, about half of which, on the west side of the river, have good loam soils, while the other half, bordering the upland, is more sandy.

Cape May Peninsula.—Geologically, this peninsula consists of the area south of a line drawn from Somer's Point to the mouth of Dennis creek. To obtain the arable portion of this area there must first be subtracted a belt on the east embracing the beaches,

and the salt marshes between them and the mainland. There must next be subtracted an area including the salt and fresh-water marshes bordering or communicating with Delaware bay. Of the remainder, there is a belt about thirty miles long and with an average width of three-quarters of a mile, just west of the salt marshes on the eastern side of the peninsula, which is tillable. There is a second strip of arable land in similar relations along the west margin of the peninsula. It has a length of eighteen miles, interrupted by several marshes, and a width of about three-quarters (average) of a mile. Between these belts the central



Fig. 1. Cape May formation, two miles south of Beesley's Point.

portion of the peninsula, some thirty miles long by two and one-half wide, is, with few local exceptions, too sandy for cultivation.

The soil of the tillable portion consists of sandy loam. It has a brown loam subsoil of about two feet in thickness, below which are the loose sands and gravels of the Cape May formation..

The relations as well as some suggestions of the character of the soil are shown in Fig. 1. The photograph here reproduced is from a point two miles south of Beesley's Point. The relations shown in the figure are fairly typical of the whole tillable part of the peninsula.

Fig. 2 represents another phase of the formation rarely seen in the peninsula. The upper two feet is gravelly loam, below which there is gravel and coarse sand, making excellent road material.

Between Tuckahoe and Port Norris, across the upper end of the peninsula, the Cape May formation is thin, and partakes of the nature of the underlying sands and gravels. The soil is sandy or gravelly, with too little loam. Many small farms have in recent years been opened up in this region, particularly in the



Fig. 2. Railway cut one-quarter mile north of South Dennis Station.

vicinity of Woodbine. They are devoted chiefly to small fruits and appear to be tilled with profit.

The Atlantic Coast.—The Cape May formation as found in Egg Harbor river valley consists for the most part of indefinite sand terraces extending as far up as Weymouth. In places, as at Mays Landing, there is a bed of stiff clay in the terrace, but such clay is nearly always overlain by two to four feet of loose, coarse sand not valuable as a soil, and rendering the clay of no avail as a subsoil. Locally there is a loamy surface giving a fair soil.

Such areas, however, probably represent less than one-tenth the area of the formation in this drainage basin.

Between the Egg Harbor and Mullica river basin, the tillable portion of the Cape May formation consists of a belt of country about three-fourths of a mile wide, from Somer's Point to Leeds' Point on Great bay, a distance of sixteen miles. The relations here are the same as in the Cape May peninsula. With increasing distance from the border of the salt marsh, the soil becomes too sandy to be valuable for agricultural purposes.

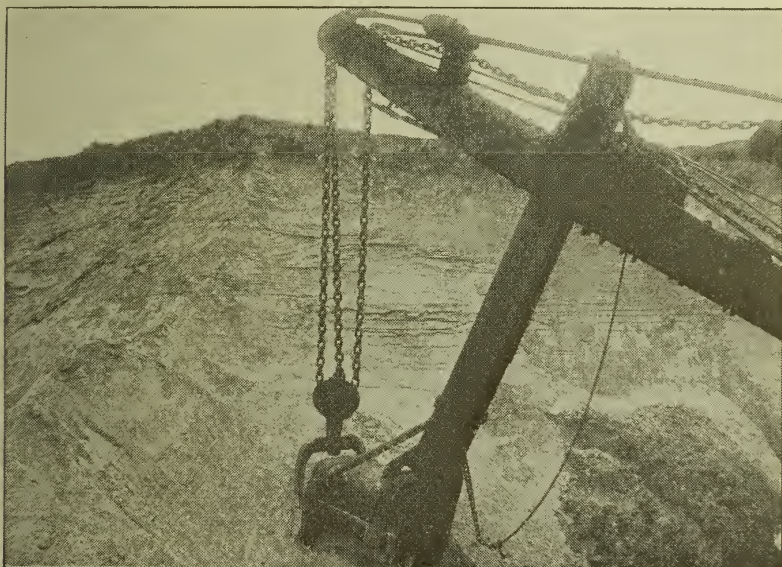


Fig 3. Railway Gravel-pits near Absecon.

The relation of the tillable soil to the formation beneath it is shown in Fig. 3, in which, as may be seen, the upper two feet or so of the section is loam, while below there is incoherent sand with occasional seams of gravel.

From the map it will be seen that a large area of the Cape May formation is represented about the mouths of Mullica and Wading rivers. About one-third of this area so represented on the map is salt marsh and fresh-water swamp, and little of the remainder has a sufficiently loamy soil to be profitably tilled.

From Tuckerton to Barnegat the Cape May formation covers a belt of country about one-half mile wide, and from Barnegat to Toms river, a belt one and one-half miles wide. About one-half of this area is tilled. The soil, like that of the Cape May peninsula, is locally good, but it has a constant tendency to become too sandy. The soil of the formation as it extends up Toms river and its tributaries, is essentially like that along the coast. From Toms river northward to Manasquan the formation covers a broader belt of coastal land. Locally it affords a good soil, but its general character is the same as farther south.

Most of the way from Manasquan to Sandy Hook the formation constitutes a narrow lowland bordering the shore. In the vicinity of Long Branch, however, it extends inland four or five miles. Between Manasquan and Shark rivers the soil of the formation is brown to yellow loam, and many good farms are located upon it, but from Shark river to Asbury Park the soil is for the most part too sandy to be valuable.

North of Asbury Park the formation is thin, consisting of but a thin mantle of loam over the Cretaceous beds, so that the latter influences the soil. In the vicinity of Long Branch, Little Silver and Eatontown the loam itself is largely derived from the Cretaceous beds beneath, so that the soil differs but little from that which belongs to the Cretaceous formation.

Along the Navesink river and its tributaries the Cape May formation is represented by terraces of gravel and sand which for the most part have a fairly good soil. Where the red sand of the Cretaceous constitutes the underlying formation, the soil of the terraces does not differ materially from that of the uplands. This is the case from Phalanx northeast, but where the Lower Marl constitutes the country rock, the terrace soils are lighter than those of the upland. This is probably largely due to the more ready underdrainage furnished by the terraces.

Raritan Bay.—Along the south shore of Raritan bay the Cape May formation mantles the low country up to about the forty-foot level, giving it a somewhat uniform surface. The soil varies from loam to sandy loam. The greater part of it is under cultivation, being devoted to such crops as flourish on light soils.

Along South river the Cape May formation covers a broad lowland. Where it borders the river this lowland has a good loam soil, particularly from Old Bridge to Spotswood; elsewhere it is too sandy to be profitably tilled.

In conclusion, it may be said of the soils of the Cape May formation: First, that they are less sandy in the valleys of the Delaware and its tributaries than along the coast, or in the valleys opening eastward. Probably about one-half of the former and one-tenth of the latter can be tilled with profit. Second, much of the land that is now tilled with profit owes its value to its low altitude. It is so low that, though it has not a retentive subsoil, it is so near the permanent ground-water surface that this water is available for the growing vegetation. Some areas which have soils essentially the same as those which are cultivated with profit are not tilled because they lie a few feet higher. Third, some portions tilled with profit owe their value to a subsoil of one or two feet of loam moderately retentive of water, while adjacent areas, in all respects similarly situated, are not tillable because this sort of subsoil is replaced by sand or gravel.

Many of the areas not now tillable would probably be amenable to improved methods of tillage, but the cheapness of land to be had elsewhere, together with the small profit on agricultural products generally, leaves but a narrow margin to warrant the extra cost of improved methods.

The soils of the Cape May formation vary so widely in character that they are not peculiarly adapted to any particular crop. They range from a fairly good wheat soil to an excellent sweet potato soil, and to the extreme of soil-less dune sands.

The value of the land for tillage can be judged to some extent from the native vegetation. The soils supporting native growths of hard wood can be relied on as having a sufficiently retentive soil for tillage; the mixed hard wood and pine growths indicate a lighter soil, but a soil still serviceable for cultivation, while the growth of pine only, and that of the smaller species, indicates a soil too sandy to be profitably tilled. To these rules, however, there are too many exceptions to allow them to be followed blindly. For example, the chestnut will thrive where there is a good subsoil, above which there may be so great a depth of loose sand as

to render it worthless for tillage after clearing. On the other hand, areas which once supported growths of hardwood may, if cleared and allowed to grow up in timber again, be occupied by pines. In time it may be difficult to distinguish such pine forests from original growths.

SOILS OF THE PENSUKEN FORMATION.

Roughly speaking, the Pensauken formation occurs in a belt near, but not at, the border of that part of the State lying south of a line drawn from Trenton to Perth Amboy. Stated in another



Fig. 4. Hylton's pit, below Palmyra. Pensauken on Raritan clay.

way, the Pensauken formation occurs just inside the Cape May formation, which lies along the coast and up the Delaware river as far as Trenton. Within the Pensauken belt the formation is by no means continuous, but appears in numerous large and small patches, many of which are too limited in area to appear on the accompanying map. This patchy distribution is the result of the erosion which has taken place since the formation was deposited. But a small part of the once continuous formation now remains.

The formation was primarily of gravel and coarse sand, and its characteristic occurrence, as now seen, is in the form of beds of gravel capping the low hills and divides of the belt within which it occurs. Figs. 4 and 5 give some idea of the formation and inferentially of the soil to which it gives rise. In Fig. 4 the lower half of the section is Raritan clay, and from the top the soil has been stripped, except at the extreme left. Otherwise the upper half of the section is characteristic of the Pensauken areas of the region where it occurs. In the section, sand and gravel appear in about equal proportions. The sand is arkose



Fig. 5. Pensauken gravelly loam at Bridgeborough, south of Burlington.

and compact, and contains some loam. Fig. 5 shows a somewhat different phase of the formation. Fig. 6, from a gravel-pit at Ellisburg, southeast of Camden, represents a common type of section as seen in the remnants of the formation between South Amboy and Swedesboro. The upper half of the section is gravel, while the lower half is coarse, arkose sand, cross-bedded and free from gravel. Along the belt running southwest from Raritan bay to the Delaware bay, the Pensauken soils are almost uniformly good for standard crops, such as corn, oats, potatoes, and generally for wheat, and are locally used for other crops as well.

The soils of the Pensauken along the coast are, on the whole, more sandy than those bordering the Delaware or running across the State from Camden to Raritan bay. In Cumberland and Atlantic counties the soil is usually sandy, the greater portion of it being uncultivated. On the other hand the Pensauken of this region includes a large proportion of the land which is cultivable.

The soils of the Pensauken formation are without doubt the most uniform of those of any formation of similar extent in the southern part of the State.



Fig. 6. Exposure in Pensauken gravel-pit near Ellisburg.

In many localities there is, over the Pensauken formation, a thin bed of silt or loam, one to three feet thick, which appears to have been deposited on the Pensauken formation at a later time. It now appears as an ill-defined mantle not readily separable from the underlying beds. This loam has a greater development in Mercer and Middlesex counties, and in the northwest corner of Burlington county near Bordentown, than elsewhere. Its presence is generally beneficial to the soils. Where this is absent, the Pensauken soils are gravelly loams; where it is

present in considerable thickness there is little gravel mixed with the loam.

SOILS OF THE BRIDGETON FORMATION.

The soils of the Bridgeton formation may be conveniently considered in two sections, those southwest of Mullica river and those northeast of that stream. Southwest of Mullica river, the soils of the Bridgeton are much like the better soils of the Pensauken. Figs. 7 and 8 give some idea of the sections of the soil and sub-



Fig. 7. Sections exposed in pit near Millville. The lower Part below the gravel-band is Bridgeton. That above is probably the Cape May Formation.

soil and their close correspondence with the Pensauken, so far as their general relations are concerned, is evident. Within the limits of the Bridgeton formation there are a few relatively large areas where the soil is more uniform than over equally large areas of the Pensauken; but, on the other hand, taking widely separated areas into consideration, there are greater differences within the area of the Bridgeton. Probably something like three-fourths of the Bridgeton area southwest of the Mullica river possesses a tillable soil, and fully half of this may be said to

possess a good soil. The areas where the best soils occur are west of Cohansey creek, between Bridgeton and Shiloh, between Bridgeton and Elmer, and in the vicinity of Vineland. Each of these localities includes areas of several square miles. Here, as in the case of the Pensauken formation, the excellence of the soils is partly due to the surface loam of later age [see p. 20].

The remainder of the Bridgeton areas southwest of the Mullica river furnish many patches of good soil, but they are generally of small extent and are liable to grade into soils which are too sandy. The Bridgeton soils are, on the whole, used for much the same purposes as those of the Pensauken formation.



Fig. 8. Cemented Bridgeton Sand; from an exposure one and a quarter miles northeast of North Woodbury.

The Bridgeton formation northeast of Mullica river, like the Pensauken of the same region, is almost uniformly too sandy for cultivation.

The soils of both the Bridgeton and the Pensauken formation are well adapted to fruit growing. Peaches especially, but pears and apples also appear to thrive on them. It is not uncommon between South Amboy and Camden, where the Pensauken beds occur in patches on the Cretaceous hills, to find

orchards on the Pensauken knolls reaching down beyond this formation to the Cretaceous clays, and to see the trees above, on the Pensauken, strong and thrifty, while those on the Cretaceous below are in relatively poor condition.

SOILS ON THE BEACON HILL FORMATION.

The Beacon Hill formation, as given on the map, consists for the most part of coarse sand which is usually incoherent. In some places the grains are coated with thin films of clay or loam which give the sand sufficient coherence to enable it to be moulded. Locally, too, considerable beds of plastic clay occur, here and there attaining a thickness of as much as twenty feet. The coarse sand is sometimes interbedded with fine sand and tough clay.

Whatever the character of the underlying beds, the soil is usually very much the same, consisting of coarse, loose, white sand which has a most forbidding appearance. At a slight distance below the surface, however, the whiteness disappears and the loam increases, so that the surface appearance of the soil is worse than its real character. Where the lower parts of the formation come to the surface, the soils are on the whole better than at higher horizons.

In the vicinity of Hammonton many clearings have been made on this formation, and have been found to be profitable for the cultivation of berries. It is possible that considerable tracts elsewhere might be used in the same way, but at present a very small proportion only of the soils of this formation are in cultivation. The formation as a whole seems to invite forest culture, rather than the ordinary form of agriculture.

SOILS OF THE MIOCENE.

The Miocene formation is for the most part fine sand, much of it being extremely fine. This sometimes serves as a fair sub-soil even where loamy matter is almost wholly absent. With the fine sand there is associated more or less clay, which locally becomes an important part of the formation. Northeast of Blackwood sand predominates, clay occurring only in thin laminæ,

but southwest of that point the formation carries more clay, and in the vicinity of Woodstown and Alloway, it is chiefly clay.

In Monmouth county, northeast of the Manasquan river, the formation gives a soil that is too sandy to be generally cultivated. Southwest of the Manasquan, on the other hand, the soil is much better, and many good farms are to be found upon it. In Ocean county the Miocene locally gives good soils, as may be seen in the vicinity of Van Hiseville, Cassville and Collier's Mills.

In Burlington county the northwest margin of the formation is tillable. It is probable, however, that the loam which furnishes the soil was not derived from the Miocene beneath it, but, like the loam covering the Pensauken and Bridgeton formations, was added later. Seven or eight miles southeast of Medford, in Burlington county, there is an area of six or eight square miles about Tabernacle and Indian Mills, reaching south nearly to Atsion, which has a good soil derived from the Miocene. The formation here has enough clay, with the sand, to give a loamy soil. This area about Indian Mills, together with the narrow belt along the northwest border of the formation, includes essentially all the tillable Miocene soil in Burlington county.

In Camden county, the northwest border of the formation, equal to about half its surface area, has a soil which is tillable, while the southeastern part is too sandy, and is, for the most part, waste. In Gloucester county much of the formation is cultivated, the soil being loamy, sometimes becoming a heavy clay loam.

In Salem county the formation is largely clay, and affords a soil which is heavy, suitable only for heavier crops, especially grass, corn and wheat.

SOILS OF THE CRETACEOUS FORMATIONS.

The Cretaceous system of New Jersey consists of a series of formations of different physical and chemical constitution, dipping gently to the southeast. They appear at the surface in a northeast-southwest belt running from Raritan bay on the north-

east to the lower course of the Delaware on the southwest. On the accompanying map the several formations of the Cretaceous system are not separately represented. The Cretaceous system of this region has been variously subdivided, but for present purposes the formations may be grouped in three main divisions—the Raritan formation, the Clay Marl series (Matawan) and the Marl series. The Raritan formation is the lowest member, and outcrops along the northwest edge of the Cretaceous belt. The Marl beds are at the top and outcrop along the southeastern portion of the Cretaceous belt, while the Clay Marls occupy an intermediate position. Reversing the order which has been thus far followed in considering the soils of Southern New Jersey, the soils of the oldest division of the Cretaceous will be spoken of first.

The Soils of the Raritan Formation.—The Raritan formation consists of numerous beds of clay, sand and gravel, no one of which is persistent for great distances. Any one is liable to displace any other in an apparently orderless way.

The soils to which the Raritan formation gives rise vary with the nature of the underlying beds, but they are, on the whole, poor. The soils of the clay beds are too clayey for general agricultural purposes, and those of the sand beds, too sandy. Furthermore, the clay is too impervious to make a good subsoil, while the sand and gravel are too open.

The belt of the Raritan outcrops is, on the whole, low, and fortunately for agricultural interests the outcropping edge of the formation is largely covered by remnants of younger formations. Through Middlesex and Mercer counties, as may be seen from the map, the Pensauken remnants are numerous along the northwest border of the Cretaceous belt, where they conceal much of the Raritan formation which otherwise would outcrop. From Trenton southwest, the Delaware has its immediate valley in this formation, and the lowland along the stream is covered by the Cape May formation. The Pensauken and the Cape May formations together therefore conceal a considerable part of the Raritan, and give to the belt where this formation comes near the surface a soil much better than the underlying beds would afford.

As already indicated, the Pensauken originally consisted of a continuous bed which overlay all the southern part of the State

up to certain definite altitudes. The outcrop of the Raritan formation was once completely covered, but subsequent erosion has so largely removed the Pensauken that remnants only, as the map shows, are now found.

The effect of the Pensauken formation on the soils of the Raritan belt is much greater than might be inferred from the map. The processes of erosion are slow, and material once started on its seaward journey stops many times before reaching its destination. Thus along the belt where the Raritan outcrops, in areas from which the Pensauken has been chiefly removed, there are still patches of gravel, sand and loam, derived from the Pensauken, which are in a sense on their way to the sea; that is, materials from this formation have in many cases been shifted from their original position to lower levels, where they now lie, making a thin cover for the Raritan.

Through Middlesex and Mercer counties enough of this displaced gravel and sand is found in the areas from which the Pensauken as a bed has been removed, to determine the character of the soil in many places. Moreover, in post-Pensauken time there has been a submergence of this region which probably left as a mantle on the Pensauken and older formations much of the loam which constitutes the soil. This loam, the displaced Pensauken, and Pensauken remnants themselves, give a soil over most of the area where the Raritan lies near the surface for which that formation is not responsible.

In most places, however, the Raritan lies near enough to the surface to affect the subsoil, and hence to determine in part the adaptability of the soil. This varies from place to place with the character of the Raritan subsoil.

Some portions of the Raritan are essentially bare, and therefore responsible for a soil. Examples are the sandy soils east of Lawrence brook, in the vicinity of Milltown; the sandy soil between Kinkora and Florence; and the sandy and gravelly (fine) soil at Red Bank, Gloucester county.

The upper, two to twenty feet of the Raritan formation, has in some places been cemented by iron oxide to a sandstone. Fig. 7 shows this type of sandstone with loose sand beneath. On weathering, this sandstone often gives rise to a ferruginous sandy loam-soil which is frequently of good quality.

The Clay Marl Soils.—The Clay Marl series, unlike the Raritan, is divisible into somewhat distinct beds. In the study of the surface formations, Mr. Knapp has found five of these beds to be so persistent that they can be traced across the State, although some of them vary in the course of their outcrops. Two of the five are essentially sand beds, two are essentially clay beds, more or less marly, and the fifth is more variable, being sometimes marl, sometimes clay and sometimes sand. Whatever may be said of the importance of these beds from the point of view of stratigraphical geology, they are of importance from the point of view of soils. The several beds have been named by Mr. Knapp as follows, commencing below: the *Merchantville* bed (marly clay); the *Woodbury* bed (dove-colored clay); the *Columbus* bed (sand); the *Marshalltown* bed (marly-clay sand), and the *Wenonah* bed (sand).

In Monmouth county, from Jamesburg northeast, the *Merchantville* bed is bare at many points, and the soil to which it gives rise is a brown ferruginous loam (sometimes sandy) so distinctive in appearance that it is easily recognized. The same soil is seen again in Salem and Gloucester counties west of Penns Grove, near Perkintown, and between Perkintown and Gloucester, mostly in small patches on valley slopes.

Between Jamesburg and Camden this bed rarely comes to the surface in flat regions where it could retain a soil, but only in the banks of streams where its soil is seldom tillable. Elsewhere it is either covered up by the Pensauken or displaced material therefrom, or along the Delaware lowlands by the Cape May formation.

Between Swedesboro and Bridgeport the *Woodbury clay* appears at the surface along a narrow belt and gives rise to a light-colored stiff clay soil. At various points along its outcrop, as in the vicinity of Woodbury, Haddonfield, Bordentown, and the State reform school east of Jamesburg, it gives rise to a clay soil over areas of varying size. In the vicinity of Matawan, Monmouth county, it constitutes the soil over a considerable area. The greater portion of the outcrop, however, is covered with a thin mantle of Pensauken or of displaced material. Over a considerable portion of its outcrop, however, where it is thus mantled, it still influences the adaptability of the soil greatly by furnishing a relatively impervious subsoil.

The Columbus Bed is not very conspicuous southwest of Monmouth county. It is largely buried by the Pensauken and its displacement material, but it is still responsible for the soil at the following points: The yellow and brown ferruginous soil at Mount Royal, Gloucester county, southwest of Woodbury; the snow-white dune sand near Bell Mawr station, north of Blackwood; the sandy soil south of Hartford station, east of Moorestown; the sandy soil, vicinity of Columbus, Burlington county, and the broad belt of sandy soil in Monmouth county from Englishtown northeast through Hazlet station to Port Monmouth, on Raritan bay.

Southwest of Monmouth county, where it gives rise to the soil or constitutes the subsoil, it is more often used for peach and pear orchards than for any other crop. In Monmouth county, while it is still used somewhat for peaches and pears, it is more largely used for berries and grapes, and for general truck farming.

The Marshalltown Bed is a good marl in Salem county, but from Gloucester county northeast it is for the most part a micaceous, black, greasy clay, or fine, ashy sand-marl, and gives rise to broad, flat regions along its outcrop. These are seen between Mount Laurel and Moorestown, northeast of Jobstown, west of Imlaystown, north of Bergen Mills, and in the vicinity of Englishtown. These flats are for the most part covered by a loam or clay loam that appears to have been derived from some other source than the Marshalltown bed. The flats are largely devoted to pasturage, and as such are susceptible of a high degree of improvement, as witness the Lorillard estate, near Jobstown.

Where the formation gives rise to the soil directly, as it does over a considerable portion of its outcrop, it gives a fine sandy loam of spongy character.

The Wenonah bed gives rise to the ferruginous sandy soil in the vicinity of Sharptown, Salem county, the broad belt of ferruginous red sandy loam-soil between Mullica Hill and Swedesboro, the sandy soil in the vicinity of Chew's Landing, the sandy soil east of Haddonfield, and in the vicinity of Evesboro, Burlington county. Farther northeast the sand in Disbrow's hill, Monmouth county, and the sandy soil about it, and the sandy soil thence

through Tennents, Robertsville, Morganville and to the Atlantic Highlands, are to be referred to this bed. Probably four-fifths of the outcrop of this formation is bare, and gives rise to the soil directly. It is always a sandy or sandy loam-soil, reddish or yellowish in color. Notwithstanding the fact that this soil is loose at the surface and liable to be blown about by the winds of spring and fall, it is fairly compact beneath the surface, and has a considerable loam content. It grows excellent peaches and pears, as witness the Roberts farm, near Evesboro, Burlington county. It has also given to the region about Swedesboro the sandy soil that has given it a more than local reputation for sweet potatoes.

The Soils of the Marl Series.—The marl series, the uppermost of the three great divisions of the Cretaceous in New Jersey, is made up of a considerable number of more or less distinct beds. The classification adopted long since by the Survey of New Jersey is much better as a basis for the discussions of the soils than the more modern ones. According to this older classification, the divisions of the marl series are as follows from the base up: The Lower Marl, the Red Sand, the Middle Marl, the Lime Sand and the Upper Marl.

The outcrop of the *Lower Marl* bed through Monmouth and Burlington counties is largely without a covering of later material, and the soil of the belt is therefore a marl residuary soil. Its typical phase is black loam, with more or less glauconite, the latter giving it a somewhat granular character. A typical development of this soil is to be seen in the vicinity of Cream Ridge, Monmouth county. When properly tilled, this soil is one of the most productive in the State, but it demands greater care than the soils of some other formations, for without proper tillage it is liable to bake or "burn out," and under such circumstances is not productive.

In the valleys of the belt where this formation comes to the surface, the soils are made up partly of Lower Marl material and partly of materials washed down from the formations outcropping on the slopes and accumulated in the valleys. Such soils are often rich, having some advantages over the soils derived from the Lower Marl alone. Examples of this class of soils are to be seen in the Swimming river valley and its tributaries.

In the Holmdel valley, which is underlain by Lower Marl, the soil is extremely rich, and is made up of a mixture of materials washed down into the valley from formations overlying the Lower Marl. In the valley the Lower Marl is but a slight distance beneath the surface, and really constitutes the lower part of the subsoil of the region.

The Red Sand formation is well developed through Monmouth county and extends thence southwest some distance into Burlington county, where it thins out. The upper ten to twenty feet of the Red Sand bed, which consists of alternating layers of green, clayey marl and sand and white clay, is to be looked upon as a transition to the Middle Marl above. The marl and sand of this upper part of the Red Sand are likely to be cemented into "Shelly" marl. On disintegration this shelly marl gives rise to a red loamy soil, while the white layers give rise to a yellowish clayey loam.

The upper part of the Red Sand has resisted erosion better than the main part of the formation beneath, and so is often found capping the hills and ridges of the belt where this formation outcrops. It gives rise to the red loam and the yellow clay loam soils of the higher flat-topped ridges north of Holmdel and west of Crawford's Corner, east of the latter place and south of Telegraph Hill, south of Middletown and south of Chapel Hill, near Atlantic Highlands. The most extensive development of soil derived from the upper marly part of the Red Sand is from West Freehold through Freehold to Colt's Neck and Scobeyville. This is one of the richest farming regions in Monmouth county, or in the State.

The main body of the Red Sand formation below the marly upper portion is more sandy, and gives rise to a much lighter soil. It is extensively used for all sorts of crops, but is especially well adapted to fruit. This type of soil is widely developed above the 30-foot level in Rumson Neck, west of Red Bank, from Phalanx to Middletown, north and west of Freehold, in the vicinity of Red Valley and Arneytown.

Reference has already been made to the fact that the upper part of the Red Sand is marly. These marly beds may as properly be regarded as belonging to the Middle Marl as to the Red Sand.

In the range of hills extending northeast from Freehold to the Atlantic Highlands, the areas where the *Middle Marl* outcrops are not great, since the hills which have a capping of the Middle Marl are generally covered by a bed of sand and gravel which conceals the greater part of the Marl. In these situations, however, the small exposures of the Middle Marl on the hill slopes give rise to loam and clay loam-soils which are washed down the slopes, covering to a greater or less extent the outcrops of the lower formations, and furnishing good soils on many slopes which would otherwise not be profitably tilled. The aggregate area of the slopes thus mantled is greater than the area of the Middle Marl from which the loam is derived.

Southwest of Freehold, in the hilly region about Clarksburg and Perrineville, the Middle Marl outcrops on the slopes above the Red Sand. The loam derived from the former has been washed down over the slopes of the latter so that the marly soil is more widespread than the outcrop of the bed. In this region, however, it should be noted that there are yellow loam-soils at elevations above the Middle Marl, which must have had a different origin.

About Shrewsbury and Eatontown there are soils derived from the upper portion of the Middle Marl which are of variable character. While some of them are good, others carry a large amount of green clay, giving a soil which does not respond well to tillage.

Through Monmouth county and the northeastern third of Burlington, the Middle Marl soils, on the whole, are less good than those of the Lower Marl and Red Sand. This is due largely to the fact that they contain too large a percentage of stiff green clay. Southwest of Pemberton the Middle Marl becomes more granular and the soil to which it gives rise is of a better quality.

In the vicinity of New Egypt there is a brownish-yellow glauconitic sand overlying the *Lime Sand* proper, but closely associated with it. The two are here considered together. In the vicinity of New Egypt the Lime Sand is several times as thick as the yellow sand above it. To the northeast, neither the Lime Sand nor the Yellow Sand is again seen until the Manasquan valley south of Freehold is reached. Here the latter is much thicker than the former. Northeast of Manasquan valley good exposures of these beds are not seen until the vicinity of Eatontown is reached. Here the Yellow Sand attains a still greater

thickness than in the Manasquan valley, and the Lime Sand beneath is not present, or is represented by so thin a bed that it has not been recognized with certainty.

Where the Yellow Sand and the Lime Sand reach the surface, there is usually a covering of loamy material not derived from their decay over their surfaces. The Yellow Sand gives character to a small area of soil in the Manasquan valley, and to a much larger area in the vicinity of Long Branch and Eatontown. About Eatontown and Long Branch the soil of the Yellow Sand is often so light and sandy as to be blown about by the wind when free of vegetation. In spite of its sandiness it yields good crops when properly cared for. In the vicinity of New Egypt the Lime Sand gives character to a small area of soil. On weathering it is leached of its lime, and the soil to which it gives rise is a reddish-brown sandy loam with some glauconite.

In general the Lime Sand lies so near the border of the Miocene and Beacon Hill outcrops, and in such topographic relations to them, that it is generally covered by material derived from those formations.

The *Upper Marl* outcrops next the Miocene, and since the latter is usually much higher than the former, the Miocene material has washed down over the Upper Marl, largely determining the soil over the latter formation. In places, as near Vincentown and Medford, and again in the Manasquan valley and northwest of Asbury Park, the Upper Marl comes to the surface in flat regions, but even here it is covered by wash from higher slopes, or by a thin bed of the Cape May formation. Upper Marl soils are, therefore, not seen in large areas.

The Reclaimed Tide Marshes.—At many points the tide marshes have been protected by dykes, and thus made available for agricultural purposes. This is true along the lower course of the Delaware, along Delaware bay, and on the Atlantic coast. In many places the reclaimed marshes are used for meadows and pasturage only, but in other cases they are cultivated with excellent results. In a few places marshes once reclaimed have been allowed to revert to their former condition by failure to repair the dykes broken down in severe floods. Tidal marshes of greater or less size have been reclaimed along the following creeks tributary to the Delaware: Pensauken, Cooper, Big

Timber, Woodbury, Mantua, Repaupo, Raccoon, and Old Man's. There is an almost continuous dyke along the Delaware from near Penns Grove to Old Man's creek. The marshes thus shut off from the Delaware are largely drained, and much of the area is devoted to corn. Farther south the tidal marshes have been reclaimed along Salem, Alloway, and Cohansey creeks, and Maurice river.

East and northeast of Maurice river, about Cape May and farther north, there are many considerable areas of marsh between the beach and the mainland. This is especially true along the lower courses of the larger streams, such as the Egg Harbor and Mullica rivers; but here there has been little attempt made to reclaim them. Some of the marshes have been ditched and otherwise improved, with the result of benefiting the salt hay, or of facilitating its harvest, but beyond this no attempt has been made to reclaim the marshes. Much more might be done in this direction.

The soils of the reclaimed marshes are somewhat uniform. They consist of brownish-black loams, sometimes almost clayey. Below the surface-soil of this sort, a few inches to a foot in thickness, the subsoil is largely of organic material, and its texture is open. At greater depths there is often mud and often considerable thicknesses of peat.

PART II.

The Extension of the Newark System of Rocks

BY

HENRY B. KÜMMEL, Ph.D.

The Extension of the Newark Rocks Into New York.

In the annual reports of the State Geologist for 1896 and 1897 the Newark rocks of New Jersey have been described in considerable detail. The New Jersey area is but a small part of a belt which stretches southwest from the Hudson river, across New York, New Jersey, Pennsylvania, Maryland and into Virginia.

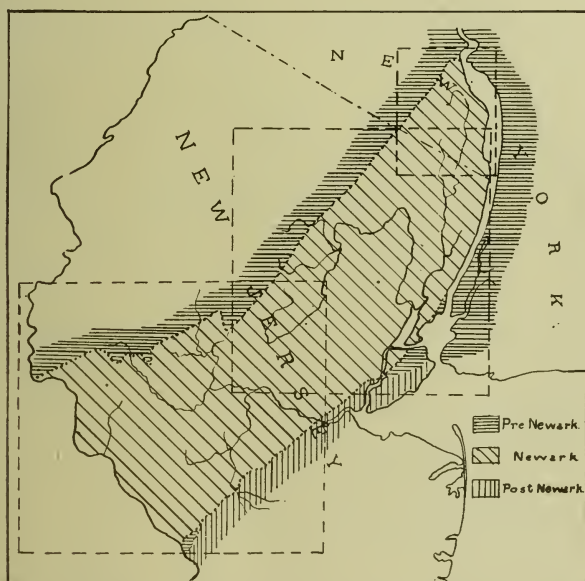


Fig. 9. Map of Newark Rocks, New Jersey and New York.

By the careful study of the New Jersey area, some progress has been made towards solving the perplexing questions concerning these rocks, the subdivisions to be made, their thickness, the conditions under which the sedimentary members were deposited, and the igneous rocks irrupted, and subsequent disturbances which the whole series has undergone. But it is clear that the fullest answer cannot be made to these questions until other parts of the belt have been carefully examined. The small area

occupied by these rocks in New York is closely connected with the New Jersey area, and is but the continuation of it. It could best be studied by one who had examined the larger region to the south, and it was hoped that its study would at least confirm conclusions already reached, even if it did not aid in settling the doubtful points. In consequence of arrangements with the New York State Survey I was able to study the area during the field season of 1898, under the direction of the late Prof. James Hall, State Geologist. Since this region is so closely connected in topography and geology with the New Jersey belt, particularly with its northern part, the results of that investigation are here summarized to supplement the former reports.

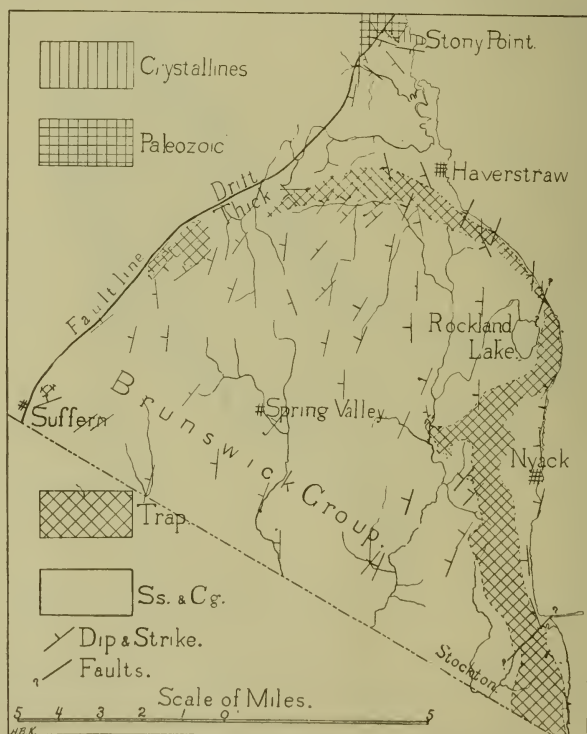


Fig. 10. Map of Newark Rocks in New York.

THE GEOGRAPHY.

The Newark beds occur in New York only in Rockland county. They occupy a triangular area, the base of which is

formed by the State line, from the Hudson river to Suffern, and the blunted apex of which is just south of Stony Point. On the east the beds disappear beneath the Hudson river, and on the west the high escarpment of Ramapo mountain, stretching north-east from Suffern to Stony Point, forms the third side of the triangle, the area of which is about 100 square miles.

The region is characterized by a rolling topography—a series of hills trending north and south, separated by valleys which have been eroded from 150 to 200 feet below the level of the hill-tops. The topography is but an extension of that which is found in Bergen county. Most of the north and south roads follow either the valleys or keep along the crests of the ridges, and are fairly level. The east and west roads cross the narrow, steep-sided ridges and are very hilly. The general level of the tops of the hills in the western part of the area is from 700 to 600 feet above the sea. Thence it declines gently eastward to the valley of the Hackensack, the inclosing uplands of which are less than 300 feet high. As in New Jersey, the Palisade trap-sheet forms a sharply-marked ridge which extends along the eastern side, close to the Hudson river. The various topographic features are intimately dependent upon the geological structure. The north and south ridges follow the trend of the beds and are due to harder and more resistant layers of sandstone and conglomerate. Along the Hackensack valley, the beds are more largely shale and the hills are somewhat lower. The massive, sharply-marked ridge of the Palisades is due to the strongly-resistant character of the trap-rock. The steeper, eastward slope of the ridges as compared with the western—a feature frequently noted where the glacial drift is not too thick—is due to the general westward slant of the strata.

THE GEOLOGY.

The Sedimentary Rocks.—As in New Jersey, both sedimentary and igneous rocks occur. The former are shales, sandstones and conglomerates; the latter chiefly diabase, or, in popular parlance, trap. The sedimentary rocks, in New Jersey, have been divided into three groups—Stockton, Lockatong, and Brunswick beds.*

*Annual Reports of the State Geologist for 1896 and 1897.

The characteristic layers of the Stockton group are arkose sandstones. In Rockland county similar beds are found beneath the Palisade trap-sheet as far north as Piermont. The beds overlying the trap-sheet for several miles north of the State line belong probably to this group. But both those below and those above the trap apparently belong to the upper members of the Stockton group, and beds of typical arkose sandstone are not abundant. From Nyack northward the beds along the Hudson appear to belong to a somewhat higher horizon than that of the Stockton beds.

In western New Jersey the Stockton beds are overlain by the Lockatong group, a series whose most characteristic layers are hard, black argillites and flagstones. These beds were not found in northeastern New Jersey, nor do they occur in Rockland county, New York. The conditions favoring the deposition of argillites and flagstones did not prevail in the northeastern part of the estuary in which the Newark beds were accumulated. In their stead were deposited red shales and sandstones, which cannot be sharply differentiated from the Stockton beds below nor from the Brunswick beds above. Owing to this fact and to the glacial drift which in many places so effectually conceals all rock outcrops, it was found impossible in Passaic and Bergen counties, N. J., and Rockland county, N. Y., to separate sharply the Stockton from the Brunswick beds, or to delimit the equivalents of the Lockatong strata.

The Brunswick beds in the southwestern part of the New Jersey area are chiefly soft red shales. Northward the shales grade into sandstones which are frequently conglomeratic. This is notably the case in Bergen county, where every exposure of any extent shows beds of sandstone and even conglomerate intercalated with the shales. This same thing is true of the New York area. The increasing coarseness of the layers continues into Rockland county, where the great mass of the formation appears to be sandstone and conglomerate, rather than argillaceous shale.

Another feature of these beds noted in Bergen county was the almost complete absence of gneiss or schist pebbles in the conglomerate beds such as were observed further north. Quartzite, sandstone, slate, shale, quartz, limestone and feldspar pebbles occur in varying proportions, but gneiss, granite and

schist pebbles are almost never met with—a fact the more surprising when it is remembered that the Newark beds are bordered for many miles by high hills of crystalline rocks. The quartz and feldspar materials in the Newark beds indicate that these areas made some contribution to the newer rocks, but the bulk of the coarser material certainly was derived from other sources. The explanation of the absence of the crystalline pebbles and, at the same time, the presence of material derived from crystalline rocks, is to be found, first, in the fault which marks the northwest border of the formation and by which a strip of limestone and quartzite has probably been cut out, and, second, in the deep disintegration of the crystalline areas during Newark times.*

In New Jersey massive conglomerates, containing cobblestones and often boulders, occur at a number of places along the northwestern border. They are chiefly of two kinds, those composed mainly of quartzite material, and those mainly of limestone. These border conglomerates do not occupy any definite horizon, but are the shoreward correlatives of the finer beds deposited in the middle parts of the estuary.

Similar calcareous conglomerates occur in New York under similar conditions and with similar relationships. Boulders of limestone five feet in diameter are known to occur, and some twelve feet in diameter are reported. The best exposures of this conglomerate are at Crum's quarry, a few miles northeast of Suffern, and at "The Limekilns," two miles south of Ladentown. Locally this conglomerate is quarried and burnt for lime.

So far as known there is no limestone along the border of the Newark beds in the immediate vicinity of the areas where the calcareous conglomerate is best developed. Outcrops of the conglomerate are found within a few hundred yards of the gneisses and schists of Ramapo mountain. Between them there are thick accumulations of sand and gravel along the valley of Mahwah creek. A narrow strip of limestone may underlie the gravel, but no outcrops of it could be found. The large boulders which sometimes occur in the conglomerate can hardly have been transported any great distance, and their presence is taken to indicate nearness to an old shore-cliff of limestone.

Near Stony Point the Newark border trends east and west for

*Annual Report of the State Geologist, 1897, pp. 55, 56, 139 *et seq.*

a distance of a mile back from the river. Here the calcareous conglomerates trend parallel to the border and dip away from the older formation, which is limestone, and which undoubtedly furnished the material for the overlying beds. The latter are basal conglomerates, resting upon the eroded and unconformable limestone beds beneath. Although these are basal conglomerates, and represent the bottom beds of the formation in this vicinity, they are not necessarily on that account to be correlated with the lowest strata of the Stockton beds, as, for instance, those exposed at Trenton or Stockton, or beneath the Palisades. While it is difficult to determine exactly their stratigraphical position respecting horizons further south, I am convinced, after a comparison of the dip and strike of all the outcrops, that these conglomerates were deposited synchronously with some part of the Brunswick beds; and that if it were possible to trace them continuously along the strike, they would be found to grade into the coarse sandstones, and thence into the fine shales, which along the Delaware overlie the black argillites and flagstones. Unfortunately, the broad waters of Haverstraw bay conceal some very interesting features of stratigraphical importance. If the above conclusion be correct, it necessarily follows that in this region the water was encroaching upon the land during middle Newark time.

The Trap-Rock. The Palisades.—The northward continuation of the Palisades forms the most important trap area in Rockland county. While in the main much like the New Jersey section, that in New York presents some interesting points of difference. For several miles north of Piermont it recedes from the river, leaving on the east a strip of lower ground, but which at Nyack has a width of about a mile and a general elevation of about two hundred feet. Two miles north of Nyack the ridge turns abruptly eastward and approaches the river, rising from it to a height of 600 to 700 feet in a steep escarpment, crowned by a high, bare cliff above and a long talus slope below. Northward for several miles from this point, known as Verdrietege Hook, the ridge rises abruptly from the river, but near Haverstraw it turns westward and continues its course away from the river for four miles, until it very nearly reaches the crystalline rocks of Ramapo mountain, on the northwestern border of the formation.



View of the Pallsade Ridge in New York: High Tor at the left; Short Clove and Long Clove.

In New Jersey the Palisade ridge is characterized by a remarkably regular crest-line which rises gradually northward to an elevation of over 500 feet near the State line. To the evenness of its crest-line and its proximity to the river is due, in large measure, the imposing wall-like structure so marked by all travelers along the Hudson river. But in New York State the crest of the ridge is decidedly irregular. Just north of the State line there is a broad sag which has an elevation of barely 200 feet, and through which, at Piermont, a small creek has cut a gap almost to sea level. Other gaps, with elevations varying from 190 to 240 feet, occur west of Nyack, at Rockland lake, at Trough Hollow, at Long Clove and at Short Clove. Between these gaps the ridge rises in a series of knobs, separated by minor depressions, to heights in general between 600 and 700 feet above the sea and reaching, in the case of High Tor, near Haverstraw, a maximum of 832 feet. The crest of the ridge, as it appears from the inner side south of Short Clove, is shown in Plate II. High Tor is shown on the left, Short Clove in the center and Long Clove on the right.

The eastern face is usually much steeper than the western. The former is frequently marked by cliffs 200 to 300 feet high, particularly where the ridge is close to the river. Where it recedes the cliffs are lower and not infrequently absent altogether. Although the western slope is in general less steep than the eastern, high cliffs are developed at a few localities, notably at a point two and three miles north of Sparkill. From Little Tor west to the end of the ridge there is but little difference in the steepness of the two slopes. The similarity in the two slopes here, as compared with the part bordering the river, is due to the different structural relation here prevailing between the trap and the sandstone. These are, in brief, as follows:

For most of its course, both in New Jersey and New York, the trap forms an interbedded sheet or sill, several hundred feet in thickness, which dips westward with the inclosing sedimentary beds. Hence the eastward escarpment is steep and precipitous and the western slope more gentle. How far downward and to the west the trap continues parallel to the bedding is not positively known, but at a number of places, both in New Jersey and New York, facts have been observed which indicate that the trap

ascended to its present geological horizon through a vertical or steeply-inclined dike, which follows closely along the western margin of the ridge. A few contacts have been found which indicate the dike structure.

The trap-sheet follows in general the strata, but many localities have been cited in previous reports where it can be seen to pass from one horizon to another, thereby cutting diagonally across the beds. Localities in New York where unconformable contacts can be seen are few, although they are known.

The unconformity of the basal contact of the trap is nevertheless readily proved. Its altitude above the river is extremely variable. At three or four points it lies beneath the water-level, at others it attains elevations of over 400 feet. These changes in elevation in some cases occur within comparatively narrow geographical limits and in most instances there is absolutely no evidence that they are due to faulting. Indeed, there is positive evidence that they usually are *not* due to this cause. Abrupt changes in the trend of the inclosing beds with reference to the shore line or the line of outcrop might cause marked changes in the elevation of the basal contact, but for the most part the sedimentary beds have a tolerably uniform strike. Moreover, much of the distance from Piermont to Haverstraw, particularly from Nyack northward, the trend of the shore and of the trap ridge is oblique to the strike of the strata, so that, as one goes northward, higher layers are constantly descending to the river and disappearing beneath the water. This slope is locally as much as six inches per yard, or 880 feet per mile. It is usually not more than one-half or even one-third of this amount, but even where least, it is sufficient to carry the basal contact from its greatest altitude far beneath the river within two miles. Since the contact is not carried permanently out of sight, and since, in many cases, it actually rises higher above the river in spite of the dip of the inclosing beds, it cannot remain at one horizon, but must break across the beds and ascend into the higher parts of the formation. Its horizon at High Tor must be many hundred feet above that at the State line.

West of High Tor the trend of the trap is often nearly at right angles to that of the sandstones which dip westward at an inclination varying from ten to fifteen degrees or from six to

nine inches per yard. This part of the ridge has less the appearance of an interbedded sill and more that of a dike than the part bordering the river, but as the northern contact is nowhere exposed it is impossible to say positively whether the base of the trap alternately dips westward with the sandstones and rises steeply across the beds, or whether it crosses them obliquely, or whether the contact is that of a dike crossing the beds at right angles to the strike. But, in any case, the relationship is such as to make the two slopes of the trap ridge nearly equal. Above the southern margin the contact is better exposed, and the dike-like character is frequently suggested. Tongues of trap, projecting into the sandstone, make the contact an irregular one. Projections from the main sheet are not unknown along the basal contact also, although their connection with the greater mass is not shown. The upper contact is strikingly irregular near West Nyack, where a spur half a mile wide, terminating in two horns, extends for nearly a mile westward from the main mass.

Further evidence of the intrusive origin of this sheet, if such were needed, is found near West Nyack and Valley Cottage, where masses of highly-indurated shale are included in the trap near its upper surface.

The thickness of the sheet is hard to determine accurately. It is the more difficult in New York, where the structural relations are more irregular than in New Jersey. At Fort Lee, a thickness of 875 feet has been revealed by a well-boring, and the total thickness here is somewhat greater than this. In New York the varying width of outcrops suggests considerable variations in the thickness. At Piermont it is probably not less than 850 feet, while at Upper Nyack, although the structural relations are too indefinite to permit an estimate of much value, the width of outcrop, here two miles, suggests that the thickness may be twice that at Piermont. But the author places very little reliance on this estimate. East of Rockland lake, where the basal contact is beneath the river level, a thickness of 610 feet is shown between the water and the crest of the ridge. To this must be added about 300 feet more, owing to the westward dip of the basal contact plane at an angle of thirteen degrees. And even then no allowance has been made for erosion along the crest and back of the ridge. North of Rockland lake the trap outcrop is

not more than an eighth of a mile in width, and the minimum thickness may not be more than 250 feet. But here the glacial drift which is banked against the western side of the ridge and obscures its true margin, adds a large element of uncertainty to these figures. It seems hardly possible, however, that its thickness is here so great as further south. At High Tor, about 550 feet of trap are exposed in the face of the escarpment, but it is impossible to determine how much must be added to this to give the correct thickness. Another 500 feet might not be too much.

Ladentown Trap.—South of Ladentown and near the northwestern border there is an irregular-shaped trap area having a maximum length of two miles and a width of one mile. Its structural relations are somewhat obscure. On both the northwestern and the southeastern sides outcrops of conglomerate dip towards the trap as if a synclinal structure prevailed. The trap is not infrequently vesicular and to a limited extent exhibits the ropy flow structure so characteristic of the extrusive sheets forming the Orange mountains in New Jersey. This resemblance, together with the apparent absence of contact metamorphism in the sedimentary beds, suggests that the trap is an overflow. Several geologists have mapped this area as a part of the Palisade sill. Between them there is a deep gap one and a half miles wide, partly occupied by a swamp and partly by thick glacial accumulations. A small outcrop of trap and one of sandstone were found within the gap. If the trap is continuous across the interval and the Ladentown area is a part of the Palisade sheet then there is reason for believing that here the trap had ascended so high in the formation that it reached the surface and overflowed. Unfortunately the data obtainable are too meagre, in my opinion, to establish beyond a doubt the unity of these Ladentown and Palisade areas.

Suffern Area.—A small mass of trap caps Union Hill at Suffern. Its structural relations are unknown. Nothing was observed to indicate positively whether it is intrusive or extrusive in origin. On the southeastern slope of the hill high ledges of conglomerate occur, dipping northwestward and apparently passing beneath the trap, but the contact is nowhere exposed. The minimum thickness is at least 125 feet.

A few small dikes were noted in the sandstones, several miles removed from any of the larger trap areas. Owing to the drift deposits they could not be traced any distance. Several small dikes were also noted in the sandstones a few feet beneath the base of the Palisade sill, and although their connection with the greater mass was not visible, they are undoubtedly offshoots from it.

Metamorphosed Beds.—In New Jersey highly metamorphosed shales and sandstones are found adjoining the intrusive trap masses, particularly along the base and upper contact of the Palisade sill. The shales are known to have been highly altered for distances exceeding 100 feet. But towards the northern part of the ridge, particularly in New York, the metamorphism is much less, both in extent and intensity, along the base of the ridge. Beds showing almost no traces of alteration are found within thirty or forty feet of the contact. Still further north, particularly west of Haverstraw, where the ridge makes its great bend away from the river and ascends so abruptly across the strata, the adjoining beds are hardly changed at all. It appears as if the nearer to the surface the trap approached, the less the contact-metamorphism. This may be due to a lower temperature and a more rapid rate of cooling of the molten rock. The fact, too, that to the north the adjoining beds are chiefly sandstones rather than argillaceous shales, may account in some degree for the lesser metamorphism, because it was observed in New Jersey that the sandstones adjoining the trap were universally less altered than the shales. Whether this is due chiefly to the differences in chemical composition or in texture, I am unable to say.

Structure.—The sedimentary beds apparently form a regularly westward-dipping monocline which may be somewhat faulted, but which is apparently but little folded (Figure 10). Within somewhat narrow limits the strike and the amount of dip vary frequently, but the variations have neither the range nor regularity requisite for the formation of folds. The dip varies from 5 to 15 degrees and the strike is usually somewhat east of north. The trend of the sandstone and conglomerate ridges is a good index of the direction of the strike and shows the relationship

between the structure and the topography. In their apparent regular monoclinical structure the beds of Rockland county resemble those of Bergen county.

Two exceptions to the monoclinical structure may be noted. For a few miles a narrow, shallow syncline, the axis of which trend northeast, affects the beds along the western border, near the Ladentown trap area. Its northward and southward extent is obscured by drift deposits, but it is probably not great.

Along the border for nearly a mile west of Stony Point the beds dip southward away from the older rocks and their strike is parallel to the boundary line. Southward the dip soon changes to southwest and then to west.

The question of faults in the New York area is rendered impossible of complete solution by the absence of distinctive horizons in the sedimentary series and to a less extent by the thick glacial deposits. Only two or three small faults were discovered in the sandstone and conglomerate areas, where the fault planes are exposed in rock cuts.

The trap ridge is undoubtedly cut by an oblique fault along the course of Overpeck creek between Sparkill and Piermont. This is demonstrated by the offset in the ridge and the abrupt change of level of the base of the trap at the line of the supposed fault. The fault has caused an offset of nearly a quarter of a mile. At Trough Hollow, north of Rockland lake, the data suggest a slight fault, but the evidence is not conclusive. The gaps at Long Clove and Short Clove have been supposed by some observers to mark faults. I found no evidence by which the question could be determined one way or the other. The ridge is not offset as is customary at fault-gaps, but this might not always occur, particularly as the trap presents here some of the features of a vertical dike. However, I am inclined to believe that if these were fault-gaps the evidence of the fact would be unmistakable.

In the Annual Report for 1897 reasons were given for believing that a large part of the northwestern border of the formation is determined by faults. The same thing is true of the New York area. With the exception of that part of the border for a mile west of Stony Point, the Newark beds are undoubtedly terminated by a fault on the northwest. The actual contact is nowhere seen, so the evidence of faulting is more or less indirect, but it is nevertheless strong. From Suffern to Ladentown the fault follows the

foot of the steep escarpment of Ramapo mountain, but the stratified drift along Mahwah creek conceals all outcrops along a belt several hundred yards wide. Northeast of Ladentown the fault appears to bend more to the east, so as to pass a little east of Theill village. Large drumlin-like hills, as well as broad kame areas, render its exact location more than usually doubtful. Beyond Theill, however, its position can be more accurately determined. About a mile west of Stony Point the boundary of the Newark beds leaves the fault, which apparently continues across the Hudson river.

The evidence of faulting is found chiefly in the fact that along the border the Newark beds usually dip towards the older rocks, or at various angles to them. Moreover, beds along the faulted border belong to widely different horizons. For many miles the fault-line trends more to the east than do the sandstones and conglomerates. Consequently lower beds are brought against the older rocks in the more northern parts of the area. Moreover, along the faulted portion of the boundary the Newark beds were not derived from the immediately-adjoining older rocks, whereas along the normal contact the older layers have entered largely into the newer beds.

On the east side of the Hudson river, above Peekskill, the topography as well as the geological structure suggest that the fault continues for several miles to the northeast along the valley of Sprout brook, but there has been no opportunity for field work in the vicinity.

The study of the Newark beds in Rockland county has disclosed no facts which call for the modification of any conclusions expressed in my previous reports. It has shed no new light on the peculiar conditions which prevailed when these beds were accumulated. No facts were observed which render it necessary to change the estimates heretofore given of the thickness of these beds or which settle the question of the extent of faulting which the sedimentary beds may have undergone. The intrusive origin of the Palisade trap-sheet has been more completely demonstrated, if such demonstration were necessary, and the fact that it does not occupy the same horizon, but departs widely from it, is proven beyond the shadow of a doubt. Further studies of the Newark beds should now be directed to their southward extension into Pennsylvania and Maryland.

PART III.

Artesian Wells in New Jersey.

BY

LEWIS WOOLMAN.

Artesian and Other Wells in New Jersey.

BY LEWIS WOOLMAN.

OUTLINE.

INTRODUCTION.

Includes geological and paleontological notes upon wells in Delaware, Maryland and Virginia, and prediction of the certainty of deep water-horizons along Delaware bay, in New Jersey.

I.

ARTESIAN AND OTHER BORED WELLS, AND ALSO DUG WELLS, IN SOUTHERN NEW JERSEY, &c.

Principal water-horizons defined and named.

Artesian Well Section, from Philadelphia, Pa., to Atco, N. J., via Delaware river bridge.

Sec. 1.--Well Records in Miocene Strata.

At Egg Harbor. Three wells.

At Ventnor, south of Atlantic City—includes notice of tidal rise and fall of the water in the well.

At Avalon—also includes notice of tidal rise and fall of water in the well.

At Lewes, Del.

Sec. 2.--Well Records in Cretaceous Strata.

At Waterwitch.

Notes respecting wells on the Highlands of Navesink and on Rumson Neck.

On Rumson Bluff. Three wells.

At Seabright, west of.

Near Oceanic.

Near Locust Point.

At Clay Pit Creek.

At Avon.

At North Spring Lake.

At Lakewood. Two wells.

At Farmingdale.

At Seaside Park.

At Toms River.

At Imlaystown.

At Mount Laurel, northwest of.

At West Palmyra.

Camden Water Works—

At Morris Station. One hundred or more wells.

In Philadelphia. Six wells. United Gas Improvement Co.

Delaware river, foot of Tioga street.

At Gloucester.

At Paulsboro.

At Fort Delaware.

At Middletown, Del.

At Rock Hall, Md.

At Fairport, Va.

At Old Point Comfort, Va.

II.

BORED WELLS, MOSTLY IN NORTHERN NEW JERSEY, IN
RED SANDSTONE, GNEISS AND OTHER ROCKS, AND
IN THE GLACIAL MORaine, MAINLY IN ESSEX,
HUDSON, SOMERSET AND MIDDLESEX COUNTIES,
ALSO ON STATEN ISLAND AND LONG ISLAND,
N. Y., AND ALONG THE DELAWARE
RIVER IN PENNSYLVANIA.

Sec. I. Wells Reported by Louis L. Tribus, C. E.

At Madison and at Chatham.

Also, Wells Reported by Wm. Wallace Christie, C. E.,

At Rutherford.

Sec. 2.—Wells Reported by W. R. Osborne.

Near Kreirschersville.

At New Brunswick, Rutgers College.

At Perth Amboy. Two wells.

Near Middlebush. Three wells.

Near Keasby's. Two wells.

At Demerest.

At and near Bonhamton. Two wells.

At Metuchen.

At Brunswick Driving Park. Two wells.

Sec. 3.—Wells Reported by Stotthoff Bros.

At Hamburg. Sussex Co.	At Sunnyside. Two wells.
At Lafayette.	At Clover Hill.
At Baleville.	At Washington Crossing.
Near Phillipsburg.	At Ewing.
Near High Bridge.	At Trenton Junction.
At Lakeview.	At Brooklyn. (N. Y.)
At Passaic. Four wells.	At Fairfield, Conn.
At Garfield.	At Mamaroneck, N. Y.
At South Orange.	At Easton, Pa.
At Lyon's Farm.	At Yardley, Pa.
At Bernardsville.	At Torresdale, Pa. Two wells.
At Hillsboro.	At Andalusia, Pa.
At Princeton. Two wells.	At Bryn Mawr, Pa. Two wells.
At Flemington. Two wells.	

Sec. 4.—Wells Reported by P. H. & J. Conlan.

At Jersey City. Two wells.	At Arlington.
At Jersey City Heights.	At Elizabeth.
At Communipaw.	At Fort Lee.
At Belleville.	In New York. Fifth Ave. & 54th St.
At Waverly.	In Brooklyn. Five wells.
At Summit.	In Connecticut. Several wells.

Sec. 5.—Wells Drilled in the Year 1891. Also Reported by
P. H. & J. Conlan.

In Newark:	At Waverly.
A. F. Bannister & Co.	At Jersey City.
C. N. Russel.	At Sewaren.
Feigenspan Brewing Co.	In Philadelphia, Pa.
Wheeler & Russel Hat Co.	Arnholt & Schaefer Brewing Co.
McAndrews & Forbes Licorice Co.	George Keller Brewing Co.
At Kearney.	Berg & Pfander Brewing Co.
At Harrison.	On Western Long Island.

ARTESIAN WELLS.

INTRODUCTION.

We present on the succeeding pages stratigraphical and geological records of such wells in the State as have come to our knowledge during the year. As in previous annual reports, they are arranged in two parts: (I) First, those that are in the unconsolidated beds in the southern or coastal plain portion of the State, and (II) secondly, those that are in the northern or more hilly and mountainous section of the State, and which is underlain by consolidated or rocky beds.

The wells in the southern part are subdivided into two sections, viz.:

Section 1. Wells in Miocene strata.

Section 2. Wells in Cretaceous strata.

The data obtained respecting the wells in these two sections and the specimens received of the borings therefrom have been carefully studied and collated. Both the data and the borings have been furnished by and through the uniform courteous co-operation of the various contractors for wells and water-works, and also of some others, financially or in other ways interested in the different water plants. To all of these we would here especially tender our thanks, while to each credit has been given in the detailed reports.

The data for wells in the northern part of the State has been obtained mainly in the form of written records likewise contributed by the various contractors and others interested. These well records are arranged in several divisions, under the separate names of those who have furnished said data.

We have added, under sections 1 and 2 of the coastal-plain wells, appropriate records of deep wells on or near the Delaware river in the State of Delaware. These elucidate the question of water-supply in New Jersey as fully as such wells on this side of the river. In fact, but few deep wells have been bored in this State along or near the Delaware bay, and such were mostly put down many years since, and were often unsuccessful, which has probably much discouraged the development of wells in this region. These failures, however, were probably due to the then more or less imperfect methods of boring. Great improvement in these methods has been made in recent years, and success is now almost uniformly attained.

These more recent successes in Delaware should therefore stimulate the development of similar wells in New Jersey near the lower Delaware river and the Delaware bay, since the same water-horizons found in Delaware are found farther to the northeast in New Jersey, and are almost certainly continuous between the two localities.

We have also added to section 2 especially interesting records of wells at Rock Hall, Md., and at Fairport and Old Point Comfort, Va.

In the Rock Hall well § there was encountered in the upper portion a duplicate of the unique mixed fresh and salt water diatomaceous deposit that occurred at Wildwood at the depths of 78 to 181 feet.*

In the Fairport well § there was found at the depth of 640 feet, a brachiopod fossil *Terebratula Harlani* Morton, which in New Jersey persistently occurs at and is confined so far as past observation has shown to the top of the Middle Marl bed. This fact might seem to indicate the continuance of this horizon southwardly across Delaware and Maryland. Recently, however, Dr. R. M. Bagg † has noted the occurrence of this fossil slightly higher in the Cretaceous in the State of Delaware, viz., in or over the Bryozoan lime sand which overlies the middle marl, and also in St. George's county, Md., still higher viz., in the base of the Eocene associated with decided Eocene oyster and other shells.

The present writer has also obtained this same species of *Terebratula* from the depth, as reported, of about 840 feet at Old Point Comfort, Va. §

We have also inserted among the Cretaceous wells in section 2 a well record at Seaside Park, § although we are not certain that it enters the Cretaceous beds at all, but if not, it must approach their upper portion very closely.

This well the writer believes, after having passed the more recent deposits near the surface, penetrated beds stratigraphically below the 800-foot Atlantic City Water-bearing Miocene sands and above the uppermost part of the Eocene beds that outcrop at Deal and Shark River. In other words, it penetrates beds between those entered by the Cretaceous wells north of Point Pleasant and those penetrated by most of the Miocene wells from Barnegat and Harvey Cedars southward along the beaches.

§ See detailed accounts of wells at Rock Hall, Md., Fairport and Old Point Comfort, Va., and Seaside Park, N. J., on later pages of this report.

* Annual Report, 1894, page 160; also pages 161 to 165, and Plates 5 and VI.

† American Geologist, December, 1898, Vol. XXII, No. 6, page 370.

I.

Artesian and Other Bored Wells, and also Dug Wells, in Southern New Jersey.

The data obtained the past year confirm the correctness of the water-horizons of Southern New Jersey as defined and named in last year's report.

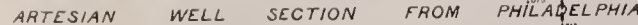
For convenience of reference to those interested, we again introduce them.

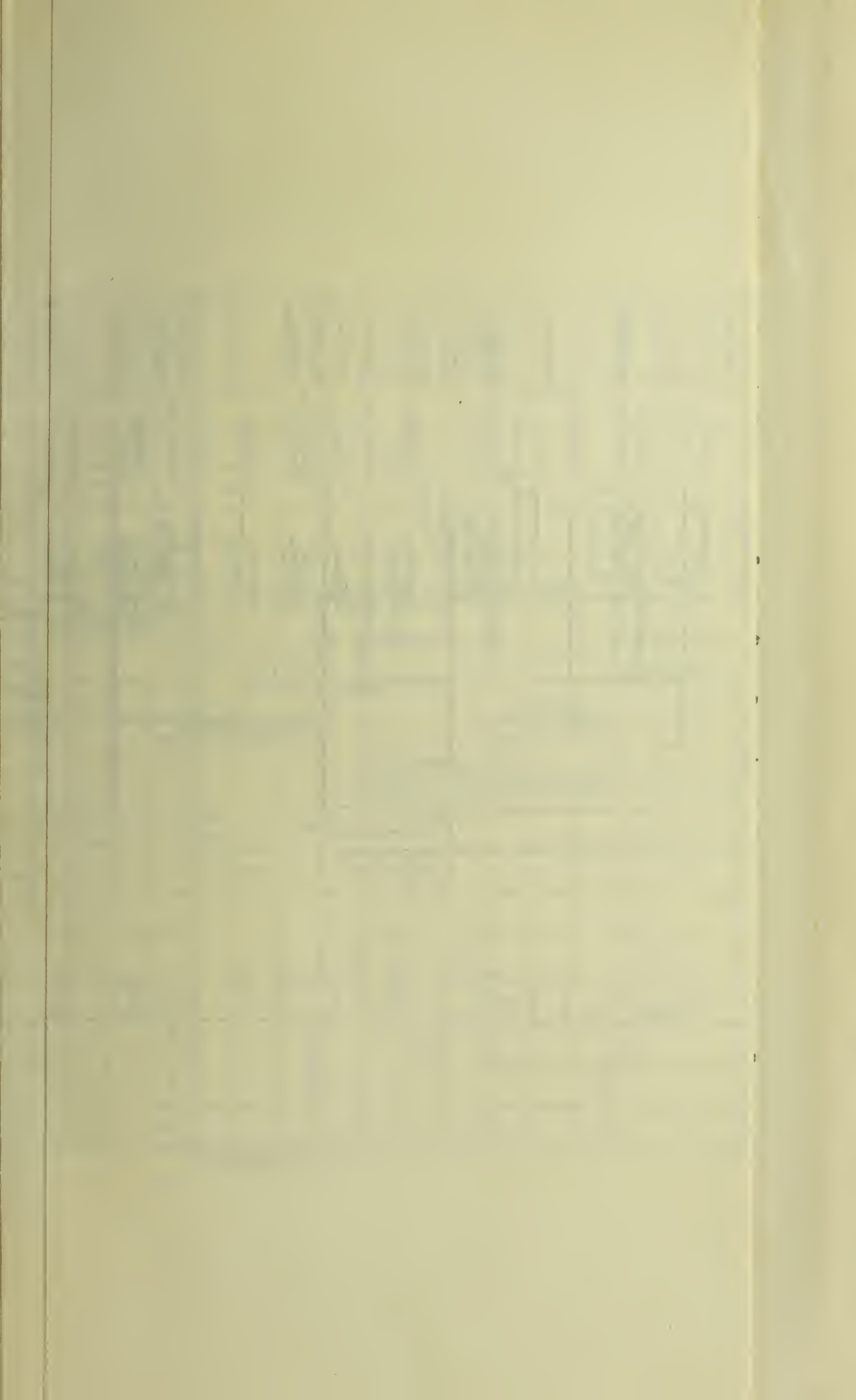
PRINCIPAL WATER-HORIZONS IN STRATIGRAPHICAL ORDER, COMMENCING AT THE TOP.

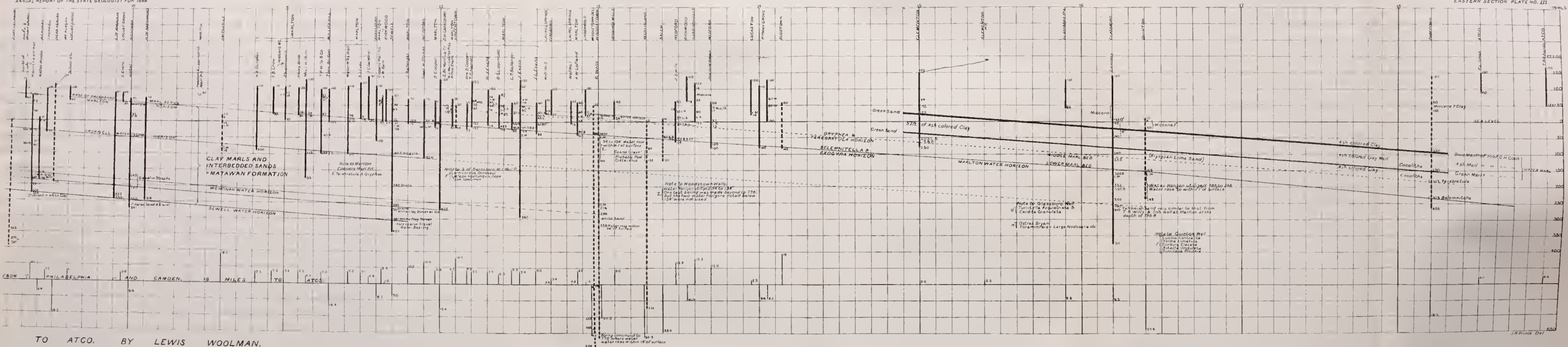
700-foot Atlantic City horizon.	}	Miocene.
Interval about 100 feet.		
800-foot Atlantic City horizon.	}	Age. ?
Interval about 150 feet.		
950-foot Atlantic City horizon.	}	Cretaceous.
Interval not yet known.		
Lindenwold horizon.	}	
Interval about 50 feet.		
Marlton horizon.	}	
Interval about 115 feet.		
Cropwell horizon.	}	
Interval 125 to 150 feet.		
Woodbury-Wenonah horizon.	}	
Interval about 70 feet.		
Sewell horizon.	}	
Interval not yet determined.		
Raritan horizons. A group.	}	

Note Respecting the 950-foot Atlantic City Horizon.—This horizon may be regarded as one not yet thoroughly defined. The only wells so far known that can draw from it are one each at Winslow, Berkeley









and Seaside Park, N. J., and at Lewes, Del.* (see page 83), and one to the 950-foot horizon at the gas works at Atlantic City. The water-horizon of the last well was, through misinformation, erroneously stated in the report of 1889 as occurring at the depth of 1,100 feet, that being the depth to which the boring was prospected. Subsequently it has developed that the water-supply came from about the depth of 950 feet. This horizon is probably near the base of the Miocene and not far above the top of the Eocene beds. In the same report we extended the Miocene much below this horizon, to the depth of about 1,400 feet, owing to what we now believe to have been wrong information as to the depths from which certain Miocene mollusks were obtained in the first and deepest of the borings made on the meadows at Atlantic City.

ARTESIAN WELL SECTION FROM PHILADELPHIA, PA., TO ATCO, N. J.,
VIA DELAWARE RIVER BRIDGE.

We have prepared (Plate III) both to vertical and horizontal scale an artesian well section for a belt of country about twenty miles in width, bordering the Delaware river on the east and parallel thereto from Bordentown southward.

The section line was drawn from a point on Richmond street, Philadelphia, south of Bridesburg, nearly directly southeast, to Atco, and is essentially coincident with the Pennsylvania Railroad Company's Atlantic City route, via Delaware river bridge, Merchantville, and Haddonfield to Atco.

The wells to the north and the south of the section line were projected against the same by means of parallel lines drawn at right angles thereto from the location of each well, said parallels trending approximately N. E. and S. W.

Wells located within about twenty miles of the section line, either to the north or to the south, are drawn in heavy solid lines, while those more than twenty miles distant, either to the north or the south, are drawn in heavy broken or dotted lines.

The section shows how, in passing from the northwest to the southeast, the Raritan plastic clays, the Matawan clay marls, and Lower Middle and Upper marl beds and their interbedded sands succeed each

*It is possible that this horizon was also temporarily opened at the depth of 1,185 feet by a test boring at Wildwood, N. J. See Annual Report for 1894, page 159.

other and are superimposed, the more easterly divisions upon the more westerly, and all of them with a gentle dip to the southeast. It also exhibits the stratigraphical position of each of the Cretaceous water-horizons that were defined in last year's annual report, pages 216 to 219, and also noted in this report, page 66. Naming them now in reverse order from that on page 66, or from the lowest upwards, they are:

The Raritan group.

The Sewell horizon.

The Woodbury-Wenonah horizon.

The Cropwell horizon.

The Marlton horizon, and

The Lindenwold horizon.

Most of the wells within the area under consideration which have been noted in past annual reports have been placed thereon. Below is a list of the same alphabetically arranged for convenience of reference. On the left we note the year of the annual report and the page therein in which each well has been recorded. On the right we note the distance on the section of each well in miles, tenths and hundredths southeastward from its initial point, near Richmond street. These distances are likewise noted at the top of the plate and may be used to find thereon the location of any well.

Annual Report.	Page.	ALPHABETICAL LIST OF LOCALITIES OF WELLS SHOWN ON PLATE III.		Distance on the section line, in miles, from Richmond street, Philadelphia.
1897	253	Atco, J. L. Grieb.....		18.5
1897	254	Atco, T. Richards.....		18.9
1896	127	Auburn.....		9.5
1896	130	Barnsboro.....		11.6
1897	256	Barnsboro, North of.....		10.1
1896	124	Billingsport.....		4.0
1896	145	Bordentown, Black Creek.....		2.8
1896	143	Buddtown.....		14.14
		Burlington.....		3.5
		Camden—		
1896	108	Armory, Haddon avenue.....		2.4
1896	110	City Hall.....		2.2
1885	125	Cooper Hospital.....		2.3
1896	109	Cooper street wharf.....		1.57
1896	111	County Prison.....		2.0
1896	106-7	Front and Elm.....		1.43
1897	268	Reeves Oil Cloth Works.....		2.75
1896	107	Seventh and Kaighn's avenue.....		3.66
1896	109	Trolley Power House.....		2.6
1896	120	Chew's Landing.....		8.4
1896	125	Clarksboro.....		7.5
1896	135	Clementon.....		15.0
		Clementon Mount, Location of—no well.....		15.4
1896	119	Colestown.....		5.9
1892	307	Collingwood.....		5.2
1896	105	Cramer Hill.....		1.7
1896	137	Cropwell.....		9.45
1897	250	Daretown.....		18.2
		Delair—		
1896	104	North of (Camden Water Works plant).....		1.65
1895	69	No. 9 Well.....		2.09
1896	226	No. 10 Boring.....		2.5
1896	228	P. R. R. Boring No. 6A.....		1.62
1896	225	P. R. R. Boring No. 7.....		1.9
		Delaware River Bridge—		
1896	224	N. J. Abutment No. 6.....		1.6
1896	222	Pier No. 2.....		1.37
1896	223	Pier No. 3.....		1.46
1896	223	Pier No. 4.....		1.5
1896	224	Pier No. 5.....		1.54
1896	221	Pa. Abutment No. 1.....		1.0
1889	85	Fellowship.....		6.8
1896	119	Fish House. No. 28 Boring.....		2.27
1896	236	Fort Delaware.....		9.2
1898	*			

*See later page of this report for record.

Annual Report.	Page.	ALPHABETICAL LIST OF LOCALITIES OF WELLS SHOWN ON PLATE III.		Distance on the section lines, in miles from Richmond st., Philadelphia.
1895	66	Gibbsboro.....		12.7
1893	407	Glassboro Cannery.....		16.2
1896	131			
1891	220			
1893	420	Glassboro Station.....		15.9
1893	406	Gloucester Gingham Works.....		4.93
1893	406	Gingham Works.....		4.95
1893	404-5	Water Works.....		5.0
1896	140	Hares Corner, Del.....		3.1
1896	126	Harrisonville, N. of.....		12.0
1894	195	Harrisonville.....		13.6
1890	265	Hartford.....		6.4
1892	304			
1896	115			
		Hog Island, Pa.....		3.0
		Cooper's Creek. Location only. No well.....		6.91
		Hopkins Farm, Haddonfield. Location only. No well.....		6.85
		Marl Pits. Location only. No well.....		6.88
1897	261	Jennings' Mills.....		13.1
		Reported as at		
1879	138	{ Columbus, }		
1882	148	{ Columbus, }		
1885	124	Jobstown... { Columbus, }		8.9
1892	305	{ Columbus, }		
1897	280	{ Jobstown, }		
		This well is near Jobstown station, Columbus being more distant.		
1896	116	Jordantown.....		3.6
1897	255	Kirkwood.....		11.66
1896	134	Laurel Springs Well No. 1.....		12.83
1896	133	Well No. 2.....		12.66
		Lenola Sta.....		5.06
1896	134	Lindenwold.....		12.92
1894	205	Locust Grove, E. Evans.....		9.95
1896	142	Locust Grove school-house.....		9.6
1895	67	Lucaston.....		13.85
1894	197	Magnolia, East of		9.9
1896	132			
		Magnolia, North of		9.3
1896	132	Mantua.....		9.05
1893	409	Maple Shade.....		4.4
		Marlton—		
1894	214	L. T. Ballenger.....		12.45
1894	210	J. Ballenger.....		11.8
1894	209	J. W. Barr.....		11.64
1894	207	Henry Brick.....		11.1
1884	125	C. B. Chew.....		10.92
1885	131			
1894	205			
		Cooper's Marl Pit. Location. No well.....		11.62
1884	126	Benj. Cooper.....		11.97
1885	132			
1894	211			

ALPHABETICAL LIST OF LOCALITIES OF WELLS
SHOWN ON PLATE III.

Annual Report.	Page.		Distance on the section lines, in miles, from Richmond st., Philadelphia.
1894	212	Wm. B. Cooper.....	12.17
1895	69	H. B. Dunphey.....	10.82
1894	212	Amos Evans.....	12.08
1894	214	J. Evans.....	12.5
1894	215	J. L. Evens.....	12.6
1894	213	W. J. Evans.....	12.3
1894	208	S. J. Eves.....	11.5
1896	143	S. C. Gardiner.....	11.55
1897	260-61	T. C. Hammett.....	12.2
1894	213	B. S. Lippincott.....	12.37
		J. G. Lippincott's marl pit. Location. No well.....	10.45
1894	206	S. Lippincott.....	11.0
1894	216	A. W. Lofland.....	12.87
1897	259	Water-works.....	11.42
1885	133	Mrs. J. Wilkins.....	11.15
1894	207		
1894	208		
1897	257	Amos Wills. } T. R. Wills & Co., }	11.25
		Medford—	
1894	218	Joseph Hinchman.....	13.7
1889	89	Isaac W. Stokes.....	11.9
1892	302		
1894	210		
1893	417	J. S. Wills.....	13.48
1894	216		
		Merchantville—	
1896	118	James A. Eagle.....	4.7
		Hinchman, No. 1, well.....	4.35
		Seashore R. R. cut. Location. No well.....	4.18
1896	125	Mickleton.....	7.4
1896	137	Middletown, Del.....	12.97
1898	*		
1893	413	Moorestown.....	6.1
		Morris Station. Hylton's pits. Location. No well.....	1.75
		Mount Auburn. Location. No well.....	9.57
1879	148	Mount Ephraim.....	6.5
1892	303	Mount Holly.....	8.8
		Mount Laurel, top of.....	9.31
1897	262	Mount Laurel. Well.....	9.35
1893	417	Mullica Hill. Thomas Borton.....	11.3
1897	266	National Park.....	4.21
1897	267	Newbold.....	5.7
		New Castle, Del.—	
1896	139	Lupton Brick Works.....	4.5
1896	139	W. & N. C. Electric R. R.....	4.9
1896	124	Paulsboro, W. Mills.....	6.7
		“ Lake.....	4.7
1896	123	Paradise, one m. W. of Thoroughfare.....	5.55
		Pavonia—	
1894	197	Camden Pumping Station.....	1.85
1892	308	P. R. R. Shops.....	2.55
1896	102		
1897	273		

*See record on later page of this report.

Annual Report.	Page.	ALPHABETICAL LIST OF LOCALITIES OF WELLS SHOWN ON PLATE III.		Distance on the section lines, in miles, from Richmond st., Philadelphia.
1892	309	Stockton Water Works.....		2.45
		Philadelphia, Pa.—		
1896	220	Carbon street well, No. 0.....		0.74
1894	198	Laurel and Beach.....		0.35
1896	114 }	League Island Navy Yard.....		3.45
1897	270 }			
1896	112	Moore street wharf.....		3.54
1896	111	Seventeenth and Washington avenue.....		0.7
1892	307	Tasker and Swanson.....		2.13
1897	271	Webster's brick-yard.....		0.55
1896	128	Pitman Grove, 190-foot well.....		14.00
1891	220 }	Pitman Grove, 130 “.....		14.05
1896	129 }			
1894	193 }	Quinton.....		16.4
1893	415 }			
1895	70	Rancocas.....		4.45
1896	140	Reedy Island.....		13.3
1891	220	Richwood, or Five Points.....		13.55
1897	249	Salem.....		13.4
1891	230 }			
1889	86 }	Sewell.....		11.7
1894	197 }			
1897	278	Smithville.....		10.6
		South Branch Mantua Creek.....		12.03
1896	126	Swedesboro.....		7.8
1896	122	Thoroughfare.....		5.6
1897	279	Vincentown.....		12.1
1896	120	Washington Park.....		5.5
1893	406 }	Wenonah Hotel.....		10.0
1894	196 }			
1894	196	Wenonah Water Works.....		9.4
1897	268	Westville.....		6.0
1896	145	White Horse.....		0.15
		West Jersey Marl Co. Old Pits (location, no well).....		12.06
		Woodbury—		
1879	147	D. Cooper.....		6.3
1879	147	C. C. Green's farm.....		7.2
1879	147	L. M. Green.....		7.25
1879	146	C. C. Green's residence.....		7.33
1879	146	C. C. Green's residence.....		7.35
1879	147	Glass Works.....		7.6
1897	265	North of.....		6.6
1895	68	Skating Rink.....		7.1
1896	121	Toll Gate South of.....		7.9
1879	146	Well No. 1.....		7.0
1891	220 }	Woodstown (six wells).....		13.0
1892	302 }			

I.

SEC. 1.—RECORDS OF WELLS IN MIOCENE STRATA.

ARTESIAN WELLS AT EGG HARBOR.

No. 1.....	Elevation, 30 feet ; diameter, 6 inches ; depth, 369 feet.
No. 2.....	“ 30 “ “ 6 “ “ 371 “
No. 3.....	“ 30 “ “ 8 “ “ 142 “

Nos. 1 and 2, Water-Horizon equivalent of the 700-foot Atlantic City horizon.
 No. 3, not yet finished ; passed three higher and more recent water-horizons.

Last year, 1897, there were reported in the annual report, page 222, wells Nos. 1 and 2. This year a third well has been located about 100 feet east of the two former wells, and has been prospected to the depth of 142 feet. Through the courtesy of Hon. Geo. Pfeiffer, the contractor for the work, and of W. H. Boardman, C. E., we have received a very full series of the borings taken mostly but two feet or so apart. We are able to make out from these a much fuller record than that furnished last year, for that portion of the section above the top of the Miocene diatom-bed. We now insert a revised record for the wells at this locality. Below the depth of 142 feet it is the same as that published last year.

RECORD WELL NO. 3.

10 feet.	Black mud ; contains fresh-water <i>diatoms</i> of recent species only.....	0 feet to	10 feet.	} 10 feet. Recent.
1 "	Very coarse gravel, pebbles iron-rust color on the outside, white inside.....	10 "	11 "	
2 "	Very coarse muddy gravel...	11 "	13 "	} 5 feet. Age. (?)
2 "	Coarse dark gravel.....	13 "	15 "	
9 "	Fine orange-yellow clayey sand	15 "	24 "	}
13 "	Coarse white sand, <i>water-bearing</i>	24 "	37 "	
8 "	Orange-yellow clay.....	37 "	45 "	}
14 "	Very fine yellow clayey sand.....	45 "	59 "	
13 "	Very fine yellow, slushy sand.....	59 "	72 "	}
6 "	Slushy, fine gravel and sand,	72 "	78 "	
6 "	Very fine dark-yellow clayey sand.....	78 "	84 "	}
10 "	Fine to coarse light-orange, yellow sands, <i>water-bearing</i>	84 "	94 "	
1 "	{ Iron stone crust or fine gravel conglomerate, 6 inches.....	94 "	94½ "	} 105 feet of orange-yellow clays, gravels and sands. Age. (?)
	{ Sandy, black clay, 6 inches ; no diatoms or other micro-organisms.....	94½ "	95 "	
2 "	Slushy, clayey, coarse sand, colored with iron rust.....	95 "	97 "	}
8 "	Dark-orange yellow coarse sand.....	97 "	105 "	
2 "	Lighter colored, slushy gravel.....	105 "	107 "	}
12 "	Light-orange colored fine yellow sand	107 "	119 "	
	Strata water-bearing, 97 feet to 119 feet.			}
1 "	Black sandy clay ; no micro organisms.....	119 "	120 "	

10 feet, Dark clayey sand; a few <i>diatoms</i>	120 feet to 130 feet.
12 " Dark sandy clay; contains <i>diatoms</i>	130 " " 142 "

CONTINUATION OF RECORD.

WELLS NOS. 1 AND 2.

Gray sandy clay.....	142	"	"	146	"
Yellowish, sandy clay.....	146	"	"	164	"
Dark clayey sand.....	164	"	"	183	"
Dark clayey sand.....	183	"	"	199	"
Dark sand with a little clay.....	199	"	"	216	"
Dark sand and clay.....	216	"	"	234	"
Clayey sand, slightly yellow.....	234	"	"	251	"
Dark sandy clay.....	251	"	"	270	"
Sandy clay, lighter shade.....	270	"	"	290	"
Sand and clay, with <i>coniferous wood</i> ..	290	"	"	310	"
Sand, brownish.....	310	"	"	328	"
Sand, gray.....	328	"	"	346	"
Sand, gray, <i>water</i>	346	"	"	371	"

Great
Diatomaceous
clay bed,
190 feet thick.

251 feet. Miocene.

Excepting one sandy specimen representing the interval between from 146 to 164 feet, every specimen from the depth of 120 feet to that of 310 feet, when examined under the microscope, showed *sponge spicules* and *diatoms*; among the latter were the characteristic specific forms only occurring in the Chesapeake Miocene clays of the Atlantic coast deposits. We regard all the beds below the depth of 120 feet as of Miocene age.

Well No. 3 enters the top of the great Miocene clay-bed at the depth of 120 feet, and Wells Nos. 1 and 2 not only enter but probably pass through the lower 190 feet of the great 300-foot diatomaceous clay-bed of the Atlantic coastal plain, and obtained water in brownish and grayish sands next beneath. The horizon is probably the equivalent of the 700-foot Atlantic City water-horizon, defined in last year's annual report, pages 218 and 219.

There is a slight difference in the elevation of Wells Nos. 1 and 2, say two feet. From the lowest one, at high tide, the water flowed over the surface. In boring Well No. 3, water in considerable quantity was found between the depths of 24 and 37 feet, 84 and 94 feet, and 97 and 119 feet. The water in the two lower of these horizons proved too irony for satisfactory use. This well was therefore finished at the depth of 37 feet, a strainer being placed at the bottom so as to draw from the white sand interval between the depths of 25 to 37 feet. We are informed the well has been "pumped 100 gallons a

minute" and that "the quality of the water is good." The horizon is the same as that reached by the dug and the other bored wells in the town, though the depth of these wells is generally much greater, they being upon higher ground.

ARTESIAN WELL AT VENTNOR, SOUTH OF ATLANTIC CITY, WITH
NOTE ON THE TIDAL RISE AND FALL OF THE WATER THEREIN.

Elevation, high tide level; diameter, 6 inches; depth, 813 feet.

This well was noted in last year's (1897) report as having reached a depth of 813 feet, but as not then completed. The well, however, was afterward finished at that depth by placing in the bottom a 50-foot strainer tube. The top of the water, yielding sand, was found at the depth of 740 feet, and the top of the great diatomaceous clay bed at 350 feet. Both of these horizons occurred in this well slightly higher, say about 25 feet, than in most of the wells that have been sunk along the beaches from Brigantine to Ocean City. The water-horizon is, however, undoubtedly that which we have heretofore designated as the 800-foot Atlantic City horizon. The difference in depth may be due to one of three causes, viz.: to slight change in strike of the beds; to slight change in their dip; or to location of the well farther back on the line of the dip. We think it probable the last is the true reason.

The well was bored for the Ventnor Land Co., by Uriah White, who kindly preserved and furnished us with a full series of the borings, which we have examined carefully by the aid of the microscope and otherwise. Below we append in record form the results of our examination.

Through the courtesy of the officers of the Land Co. we were afforded the opportunity, after the completion of the well and before its connection with the water-supply system, to have a series of observations made covering a period of nearly three weeks, showing a tidal rise and fall of the water in the well regularly following the rise and fall of the water in the ocean, and approximately three-fourths of an hour later. These observations were made by James C. Calvert, the postmaster at Ventnor. A study of his measurements shows that the difference between two consecutive tides varied from $7\frac{3}{4}$ to $14\frac{1}{2}$ inches. The minimum difference between the highest low tide, March 12th, P. M., and the lowest high tide, March 14th, P. M., was $7\frac{3}{4}$ inches,

and the maximum difference between the highest high tide, March 9th, P. M., and the lowest low tide, March 14th, P. M., was $15\frac{1}{2}$ inches.*

We here insert the record before alluded to. It is made out from the specimens, unless otherwise stated.

Ordinary beach sand, as described (no specimen).....	0 feet to 20 feet.	Recent. 30 feet.
Gray sand, very slightly clayey, contains marine diatoms and a few faint oval transparent discs with a sulcus lengthwise of the centre (the nature of these discs not determined).....	20 " to 30 "	
Both the diatoms and the discs are microscopic and cannot be seen by the unaided eye.		
Interval (no specimens).....	30 " to 60 "	
A specimen of white clay was found on the end of the drill when withdrawn from the well that is thought by the driller to have come from about the depth of.....	60 "	
It is possible, however, that it may have come from next below the depth of 65 feet.		
It contains no micro-organisms, nor any molluscan remains, and resembles the white clays found nearly opposite to the westward, in certain brick clay pits near Bakersville, on the mainland.		
Dark gray coarse sand, somewhat clayey, with fragments of shells, apparently <i>Anomia</i> , and a very small <i>clam</i> , species undeterminable from the fragments obtained	60 " to 65 "	Age. (?) 210 feet.
Interval (no specimen).....	65 " to 70 "	
Very sandy clay, slightly yellowish, the sand medium coarse; no shells nor other fossils.....	70 " to 80 "	
Alternations of gray, whitish, brownish-yellow and decidedly orange-yellow sands.....	80 " to 180 "	
Coarse brownish-gray, very sandy clay....	180 " to 185 "	
Coarse brownish sand.....	185 " to 195 "	
Alternations of gray and slightly yellowish sands—the latter the shade of a good quality of brown sugar.....	195 " to 240 "	

*See similar observation at Avalon, pages 78 and 79.

Alternations of dark brown and slightly greenish clayey sands and sandy clays with no micro-organisms.....	240 feet to 350 feet.		
Diatomaceous clays.....	350 " to 500 "		
Twelve specimens were furnished for this interval. Every one was rich in diatoms.			
The same Diatomaceous clays probably continued.....	500 " to 650 "		
Four richly diatomaceous specimens, with the marks on the labels obliterated, probably represented this interval, making in all three hundred feet of diatomaceous clays—a thickness also heretofore found in the wells along the Absecon beach.			
Sandy shell bed.....	650 " to 700 "		
<i>Miocene mollusks</i> in abundance.			
Brownish-gray sand.....	700 " to 760 "		
Fine gravel, with <i>miocene mollusks</i> quite plentiful.....	760 " to 770 "		
Gray and brownish coarse to fine sands—quite coarse on top at say 770 to 780 feet	770 " to 813 "		
Water-bearing horizon the equivalent of the 800-foot Atlantic City horizon.			

}
 Great diatomaceous
 clay deposit.
 300 feet thick.

}
 Fossil
 Mollusks.

}
 Miocene. 573 feet. (?)

ARTESIAN WELL AT AVALON, WITH NOTES ON THE TIDAL RISE AND FALL OF THE WATER THEREIN.

Elevation, 10 feet or less; depth, 925 feet.

Diameter, 10 inches to 80 feet.

" 8 " to 383 " { to top of the Miocene diatomaceous
clay-bed.

" 6 " to 750 " to a thin rock seam.

" 4½ " (with a 50-foot strainer at the bottom) to 925 feet.

Water-horizon at 875 to 925 feet.

Water rises about 8 to 9 feet above the surface, varying in height with the tides.

Flows 75 gallons a minute.

About the time of the opening of the summer season at the seaside resorts, Uriah White completed the boring of an artesian well at Avalon, at the northern end of Seven Mile Beach. Through the courtesy of contractor White and his assistants and of B. F. Sweeten & Co., contractors for the water-plant, we have received a very full series of the borings and much information. After careful study of

the specimens both with the microscope and without we are enabled to make out the record which we present below.

Opportunity was afforded on the completion of the well to make measurements and secure data respecting the tidal rise and fall of the water therein. The observations extended over a period of eight days from July 8th to the 15th, both inclusive.

In brief, it may here be stated that the difference between consecutive high and low tides in this well varied from $10\frac{1}{2}$ inches to $15\frac{3}{4}$ inches, while, however, the minimum difference, or that between highest low tide, July 13th, A. M., and the lowest high tide, July 14th, P. M., was $7\frac{1}{2}$ inches, and the maximum difference, or that between the highest high tide, July 12th, P. M., and the lowest low tide, July 14th, A. M., was $19\frac{1}{4}$ inches. Our observations the past season definitely show that the height of the water in this and other artesian wells along the coast rises with each high tide to a greater or less elevation, according as the tides on the shore are greater or less in height, and similarly falls with each low tide to a less or greater height in the casing in accordance with a less or greater fall of the tides off shore. In this well the water rose above the surface to a height varying with the status of the tides from 7 feet $8\frac{1}{4}$ inches to 9 feet $3\frac{1}{2}$ inches.*

Beach sand.....	0 feet to	20 feet.	} Recent.	50 feet.	} Age. ? 100 feet.	
Dark muddy sand, slightly greenish at the base; fragments of <i>small</i> <i>bivalves</i> , species not determin- able, at 35 feet.....	20	" "				
Streak of whitish clay at.....		50 "	} Fossiliferous.			
Gray sand, with fragments of <i>small</i> <i>mollusks</i> (bivalves).....	50	" "				
Medium-coarse dark clayey sand; shade the same as at 20 to 50 feet; <i>comminuted shell</i> through- out; also contains <i>Foraminifera</i> and <i>Diatoms</i>	70	" "				
Medium-coarse and then fine sand; shade of brown sugar; no shells	100	" "				
Whitish sand.....	120	" "	} Non-fossil- iferous.			
Deep orange-yellow sand, medium fine.....	140	" "				

* See similar observations at Ventnor, pages 76 and 77.

Dark clayey sands.....	150	feet to 180 feet	} Miocene. ? 130
Dark sandy-clay.....	180	" " 190 "	
Dark though slightly lighter clayey sand.....	190	" " 210 "	
Dark, sandy clay, slightly greenish..	210	" " 230 "	
Light-colored sand.....	230	" " 270 "	
Mixture of coarse sand and medium-size gravel; color same as stratum next above, contains			
Water	270	" " 280 "	
Mixture of sand and coarse gravel; slightly greenish in shade and somewhat clayey.....	280	" " 300 "	
Greenish-gray sand, somewhat clayey to the top of the great diatom clay deposit.....	300	" " 385 "	
Hard, greenish, <i>slightly sandy</i> clays; specimens for this interval were taken every ten feet, and all were found, on microscopic examination, to contain Marine diatoms and some sponge spiculas	385	" " 580 "	
A few inches of rock, probably indurated sand-rock, at 475 feet; at 510 feet and at 550 feet, molluscan shells; 520 to 580 feet, greenish, <i>very sandy</i> clays.			
Greenish-gray sand, Fossil <i>shells</i> in abundance, but much comminuted by the drill.....	580	" " 590 "	
Very sandy greenish clays.....	590	" " 720 "	
Specimens from every ten feet show <i>diatoms</i> and <i>sponge spiculas</i> throughout.			
Hard, greenish clay, <i>richly diatomaceous</i> throughout.....	720	" " 750 "	
Rock seam, 18 inches thick, at the base of this stratum.			
Medium gravel, mixed with clay; abundance of fossil <i>Miocene shells</i>	750	" " 760 "	
Black clay; a few <i>diatoms</i> ; base of the diatom clay-bed.....	760	" " 770 "	
Alternations of gravel, sand and clays; <i>Miocene mollusks</i> throughout.....	770	" " 815 "	
Greenish, sandy clays; no mollusks and no diatoms nor sponge spiculas.....	815	" " 870 "	
Dark gray sand, slightly brownish cast	870	" " 900 "	
Sands, slightly lighter shade.....	910	" " 925 "	
Water-bearing strata, 870 to 925 feet.			

Great diatomaceous clay deposit 385 feet thick.

Miocene. 645 feet.

The water-horizon opened is the equivalent of the 800 foot stratum at Atlantic City and the 887-foot stratum at Wildwood, and probably the 911-foot horizon at Lewes, Del.

There were encountered in making this boring five seams of rock, varying from a few inches to a foot or more in thickness. Four of these are noted in the above record. These rock-seams are probably lenticular beds of indurated sands or clays. One peculiarity of their occurrence in wells bored along the New Jersey coast into the same Miocene beds that are penetrated by this well is, that such seams are absent from Harvey Cedars to Longport, and are present from Ocean City to Wildwood, N. J., and Lewes, Del., their number slightly increasing southward from Ocean City.

Respecting the diatoms noted in the record as occurring associated with foraminifera, near the top of the boring, between the depths of 70 and 100 feet, it may be stated that Prof. Charles S. Boyer has carefully studied the assembled forms and has identified them. He writes as follows:

"The deposit is Marine and is almost identical with recent deposits found along the southern coasts, especially the coasts of North and South Carolina. It contains many forms still found in Delaware bay, but the deposit as a whole may be taken as including forms which are not now characteristic of our northern coasts and which are still more recent than Miocene. No forms strictly characteristic of the Miocene were noticed. The Port Penn, Del., deposit* somewhat resembles it, also the Bridgeton and Buckshutem.

"The accompanying list is correct as far as it goes. There may, perhaps, be a few more.

- " *Actinocyclus Ehrenbergii*. Ralfs.
- Actinocyclus subtilis*. Greg.
- Actinoptychus undulatus*. (Bail.) Ralfs.
- Aulacodiscus Argus*. (Ehr.) Wm. Sm.
- Auliscus pruinosis*. Bail.
- Biddulphia rhombus*. Wm. Sm.
- Campylodiscus Echineis*. Ehr.
- Cerataulus turgidus*. Ehr.
- Coscinodiscus radiatus*. Ehr.
- Eupodiscus radiatus*. Bail.
- Eunotogramma debilis*. Grun.
- Melosira sulcata*. Ehr.
- Navicula Crabro*. (Ehr.) Kütz.
- Navicula Henedyi*. Wm. Sm.

* A mud occurring on the bay shore and barely exposed at low-water mark.

Navicula maculata. Bail.
Navicula prætexta. Ehr.
Navicula Smithii. Bréb.
Opephora Schwartzii. (Grun) Petit.
Pseudauliscus radiatus. Bail.
Rhaphoneis Belgica. Grun.
Triceratium punctatum. Bright."

At Wildwood, ten miles southward, in an artesian well reported in the annual report for 1894, two post-Miocene diatomaceous clays occurred, one at the depth of 29 to 46 feet and the other at the depth of 78 to 179 feet.* The latter contained a mixture of marine and fresh-water diatoms, and was unique in being, up to that time, the only one known beneath the coastal plain containing two rare forms, one a species of *Hydrosera* and the other a species of *Polymyxus*.† Neither of these rare forms nor scarcely any fresh-water diatoms occur here. Nevertheless, the lithological resemblance of the non-diatomaceous material in this well at 30 to 50 feet, and its depth, would seem to correspond with the upper of the first two diatom beds at Wildwood, while, similarly, the diatomaceous material we have at 70 to 100 feet here seems to correspond with the lower of the same two post-Miocene diatom beds at Wildwood. The absence of the fresh-water diatoms at this point may, perhaps, be due to the lack of any fresh-water influence from the Delaware river so far north of its mouth.

The great Miocene diatomaceous clay-bed occurs between the depths of 385 and 770 feet, thus showing a thickness in this well of 383 feet. This is in harmony with developments of other wells along the coast which have proved that this bed thickens as we go southward.

Its thickness at various points is as follows :

At Asbury Park.....	78 feet.
At Harvey Cedars.....	151 "
At Beach Haven.....	253 "
At Brigantine.....	281 "
At Atlantic City. Meadows.....	290 "
At Atlantic City. Beaches.....	300 "
At Longport.....	372 "
At Ocean City.....	380 "
At Sea Isle City.....	393 "

* Annual Report 1894, pages 159 to 165 and Plate V.

† A similarly unique bed, containing the same *Polymyxus* (*P. coronalis* L. W. Bailey) and a mixed assemblage of fresh and salt-water diatoms, has this year been found at a similar depth at Rock Hall, Md., on the Chesapeake. It is probably synchronous in age with the Wildwood bed. See Report Rock Hall Well on a later page.

At Avalon (as above noted).....	385 feet.
At Wildwood.....	423 "
At Lewes, Del., thickness not accurately determined, but about.....	400 "
At Crisfield, Md.....	406 "

Excepting at Harvey Cedars and Asbury Park the top of this bed has been quite uniformly met with at the depth of about 380 feet, or in other words that is its depth on all the beaches in New Jersey south of Brigantine, on Brigantine Beach.

Time at command has not permitted the identification and listing of the mollusks and diatoms noted in the record. The mollusks, however, comprised the usual characteristic Miocene species, while among the diatoms there occur those peculiar forms especially and only characteristic of the great Miocene diatom bed of the Atlantic coastal plain.

ARTESIAN WELL AT LEWES, DEL

Elevation, 5 feet; depth, 1,080 feet; water at 400, 625, 750, 911 and 1,080 feet.

At 1,080 feet water overflowed about 15 gallons a minute. Water did not flow over the surface at the four higher horizons noted.

Two Miocene diatom beds, an upper and a lower.

As we were preparing for publication the well-records of this annual report we received from J. H. K. Shannahan information that he had commenced, late in the year, the boring of a well at Lewes, Delaware, and had reached a total depth of 1,080 feet, finding water at five different depths, as noted above. The water from the two lowest horizons is said to be quite salty. These two horizons, more accurately stated, occur between the depths of 891 and 950 feet, and the depths of 1,064 and 1,080 feet. We regard these two horizons as the equivalent of the water horizons defined (page 66) as the 800 and the 950 feet Atlantic City water-horizons. Why either should develop as saline water-bearing beds we are at present unable to understand.

The water from the first four horizons did not flow over the surface, while that from the lowest horizon (1,064 to 1,080 feet) overflowed ten to fifteen gallons a minute, and was pumped at the rate of thirty eight gallons a minutes. J. H. K. Shannahan courteously saved a pretty full series of specimens of the borings, which he forwarded to us, together with some notes descriptive of the beds pene-

trated. After careful study, both of the notes and the borings, we present the record on pages 85 and 86, which we believe to be accurate.

On comparing the borings and the records of this well with the borings and the records of the wells at Avalon and Wildwood, there is found to be a close correspondence for all the beds below the depth of about 300 feet to that of about 900 feet, while there is an equally close correspondence from 900 to 1,080 feet with the strata at Wildwood, as revealed there by a boring that was prospected somewhat deeper, say to the depth of 1,244 feet. These correspondences we tabulate below, adding a fourth line, showing correlation with Atlantic City borings. The figures indicate the depths from the surface in feet :

	Non-diatomaceous clay.	Shell bed St. Mary's fauna.	1st or Great Miocene Diatomaceous clay-bed.
Lewes, Del.....	294 to 407 ft.	396 to 402 ft.	407 to 772 ft.
Wildwood, N. J	294 " 370 "	396 " 409 "	370 " 793 "
Avalon, N. J.....	280 " 385 "	Not observed	385 " 770 "
Atlantic City, N. J.....	.....	Not observed	370 " 730 "

	Water Horizon.	Top of 800-foot Atlantic City Water Horizon.	Top of 950 foot Atlantic City Water Horizon.	2d Miocene Diatomaceous clay-bed.
Lewes, Del.....	625 ft.	891 ft.	1064 ft.	950 to 1080 ft.
Wildwood, N. J...	625 "	887 "	1185 " (?)	1040 " 1060 "
Avalon, N. J.....	Not observed	875 "	Not reached	Not reached
Atlantic City, } N. J., } ...	{ Not certainly observed.	775 to 835 ft.	925 to 950 ft.	{ Not observed but prob- ably passed through.

RECORD.

Surface sand, changed to sandy clay at the base; the latter contained <i>Moluscan fossils</i> broken by the drill into innumerable and consequently mostly unrecognizable fragments, but evidently the same species as those named in the next lower stratum.....	0 feet to	40 feet.	Recent.
Medium coarse gray gravel.....	40 " "	50 "	
<i>Solen Americanus</i> , Gould.			
<i>Mulina lateralis</i> , Say.			
<i>Nassa trivittata</i> , Say.			
<i>Anomia</i> ——— sp ? *			
Orange-yellow gravel, similar size to the gray gravel next above.....	50 " "	60 "	
Same fossils as next above, with the addition of <i>Tellina tenera</i> , Say.*			
Orange-yellow clay.....	60 " "	70 "	
Coarser yellowish-white gravel.....	70 " "	80 "	
<i>Nassa trivittata</i> , Say.			
<i>Natica duplicata</i> , Say.*			
Dark sandy clay.....	80 " "	125 "	Age. (?)
Specimen at 100 feet contained some lignite. Specimen at 109 feet showed comminuted shell.			
Fine gray sand.....	125 " "	149 "	
Coarser brownish sand.....	149 " "	160 "	
Greenish clayey sand.....	160 " "	165 "	
Brownish clay.....	165 " "	185 "	
Coarse brown sand.....	185 " "	200 "	
Gray sand.....	200 " "	294 "	
Some lignite at 268 feet. Clay streak at 277 feet.			

Clay (not diatomaceous).....	294 feet to	385 feet.
Rock, 2 feet.....	385	" " 387 "
Clayey sand, or very sandy clay.....	387	" " 393 "
Rock, 3 feet.....	393	" " 396 "
Clayey sand, or sandy clay..	396	" " 402 "

Contains *molluscan fossils*, comminuted by the drill, and therefore not determinable, but probably the equivalent of the *St. Mary's fauna*.

Rock, 5 feet.....	402	" " 407 "
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Diatomaceous clay, "sometimes a little sandy"....	407	" " 568 "
---	-----	-----------

Interval; no specimens or notes; probably mostly clay or sandy clay.....	568	" " 595 "
--	-----	-----------

Clay, probably diatomaceous.....	595	" " 632 "
----------------------------------	-----	-----------

Contained a sand seam, with *water*, just above 625 feet.

Sand described as greenish, but specimen has dried out to a dark brownish cast.....	632	" " 654 "
---	-----	-----------

Contains some *comminuted shell*; is not a greensand marl, but is *diatomaceous*. Contained also minute *Echinus* spines.

Sand, lighter brown; contains diatoms...	654	" " 658 "
--	-----	-----------

"Gray sand and clay mixed".....	658	" " 730 "
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"Pretty hard rock, 10 inches," say.....	730	" " 731 "
---	-----	-----------

Interval; no specimen; probably diatomaceous clay.....	731	" " 760 "
--	-----	-----------

Gray sand, <i>diatoms</i>	760	" " 767 "
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Interval; no specimen.....	767	" " 772 "
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"Rock seam at 772 feet," say.....	772	" " 773 "
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"Lead-colored clay".....	773	" " 789 "
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"Rock, 9 inches," say.....	789	" " 790 "
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"Dark green sandy clay".....	790	" " 850 "
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"Light green clay".....	850	" " 870 "
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Sandy clay (?).....	870	" " 883 "
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"Rock at 883 feet," say.....	883	" " 884 "
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"Clay".....	884	" " 891 "
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Sand, with <i>water</i>	891	" " 950 "
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Diatomaceous clay.....	950	" " 1000 "
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Greensand marl mixed with clay. <i>Diatoms</i> and <i>Coccoliths</i>	1000	" " 1020 "
--	------	------------

Rock seam, say 1 ft....	1020	" " 1021 "
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Sand and small <i>shells</i>	1021	" " 1064 "
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White sand, <i>water-bearing</i>	1064	" " 1080 "
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Diatomaceous clay at.....		1080+
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1st Miocene Diatomaceous clay-bed
does not contain *Heliopelta*.

Miocene.

2d Miocene
Diatomaceous
clay-bed contains
Heliopelta.

As in the well at Wildwood, as was noted in the Annual Report for 1894, so also in this well microscopic examinations of the borings have revealed the existence of two Miocene diatomaceous clay-beds of considerable thickness.

In this well, as noted on the preceding tabular statement (page 84), the upper one is at least 365 feet thick (407 to 772 feet). It belongs to what the writer has designated in well-records in former annual reports of this survey as the great 300 to 400 foot Miocene diatomaceous clay bed of the Atlantic coastal plain. The lower bed is, perhaps, 130 feet or more in thickness (950 to 1,080 + feet). It is quite diatomaceous between 950 and 1,020 feet, where the bed becomes largely glauconitic, a condition that continues to the depth of 1,080 feet, where it again becomes diatomaceous, and indeed very richly so, as shown by a small specimen of clay received from J. H. K. Shanahan, which he states "came from the bottom of the well," and which we apprehend represents a decidedly non glauconitic diatomaceous clay stratum upon the top of which he seems to have stopped boring.

Both the upper and the lower of these two great diatom beds contain many species of diatoms in common. In fact, the assemblage of forms is much the same in both, and both contain many of the particular forms known to diatomists as especially characteristic of the great diatom bed, or the upper of the two beds now being considered.

THE DIATOM, *ACTINOPTYCHUS HELIOPELTA*, GRUNOW*.

Characteristic of the Base of the Miocene of the Atlantic Coastal Plain.

There is one diatom, however, *Actinoptychus Heliopelta*, Grun., which is confined to the lower bed only, and which the writer deems characteristic of a definite horizon, to wit, the base of the Miocene near its junction with the underlying Eocene greensand marl.

In numerous microscopic examinations made by the writer during several years past of Miocene clays from well-borings and from outcrops, ranging from Asbury Park, N. J., to Richmond and Petersburg, Va., this stratigraphic position of *A. Heliopelta* has been abundantly confirmed. This evidence we now briefly summarize.

A. Heliopelta has been found absent from the upper diatom bed where penetrated by wells at Barnegat Landing, Harvey Cedars,

* This diatom was figured in the Annual Report for 1894, Plate VI, page 172. It has a flat, circular disc with a perfect star in the centre. This star has variously four, five, six or more points, which constitute varieties of the species.

Beach Haven, Brigantine, Atlantic City, Ventnor, Longport, Ocean City, Sea Isle City, Avalon, and Wildwood, N. J., Lewes, Del., and Crisfield, Md., while in the lower bed it *has* been found in well-borings in New Jersey, at Asbury Park (depth 40 to 90 feet), and at Wildwood (depth 1,000 to 1,060 feet); in Delaware, at Lewes, as just noted, and at Clayton (depth 100 to 150 feet), and in Maryland, at Crisfield, at the depth of 780 feet, in a stratum at the top of a bed of Eocene (?) greensand 129 feet thick.

In outcrops of the lower bed *A. Heliopelta* occurs in New Jersey at N. W. Asbury Park, near Whitesville, and in the clays of the well-known Miocene shell-outcrops near Shiloh.

In Maryland it so occurs in the clays of the bluffs on the eastern side of the Patuxent, at Lyons Creek and Nottingham, and in Virginia, at Petersburg, and in Bermuda Hundred.

To the above we may add that at the Nottingham, Md., locality the *Heliopelta* Miocene bed may be seen resting immediately upon the Eocene marl. In fact the writer has personally obtained in situ from the junction of the beds a lump of indurated earth showing on one side the greenish Eocene marl and on the other a yellowish or salmon-colored Miocene sandy clay, containing two characteristic molluscan forms, *Ephora quadricostata*, Say, and *Pecten Humphreysii*, Conrad, and also *Actinoptychus Heliopelta*, Ehr., and other diatoms.

This specimen, showing the two molluscan fossils, is now in the collections in the Museum of Friends' Boarding School at Westtown, Chester county, Pennsylvania.

C. L. Peticolas, of Richmond, Va., who made for the writer two cleanings of the diatoms from the lower bed, one at 950 to 988 feet, and the other at 1,000 to 1,020 feet, in a letter accompanying the transmission of the same, incidentally noted the occurrence in both, along with *Actinoptychus Heliopelta*, Grun., which he says is plentiful, of the following forms:

Aulacodiscus Crux, Ehr.
Aulacodiscus Solitarius, Norm.
Molosira marina, Kutz.
Sceptroneis gemmata, Grun.

Bacteriastrum, Sp. ?
Actinoptychus, several species.
Coscinodiscus, several species.
Grammatophora marina, Lyngb, Kutz.

Subsequently C. L. Peticolas made a cleaning from the upper or great 300 to 400-foot bed, from the depth of 568 to 767 feet, and writes, upon transmitting it, that "the upper like the lower bed is exclusively marine and shows many of the same forms but,

[that] there are important differences," among which he states that "Actinoptychus Heliopelta does not occur in this [the upper] bed." He thus independently confirms the writer's previous observations respecting this diatom, and thus cumulatively helps to prove the conclusions of the latter as to the stratigraphic value of this microscopic fossil. At 568 to 767 there are also a few Polycistna and Foranminifera—the latter mostly of the genera Textularia and Globigerina.

Associated with the diatoms at 1,000 to 1,020 feet are quite a number of Coccolith and Rhabdoliths, minute calcareous objects whose nature is not understood. They are much smaller than diatoms in general are.

Prof. C. S. Boyer has kindly identified the diatoms at 1,000 to 1,020 feet and has furnished the following :

MIocene MARINE FOSSIL DIATOMS, AT LEWES, AT THE DEPTH
OF 1,000 TO 1,020.

BY CHARLES S. BOYER, A. M.

- Actinocyclus Ehrenbergii, Ralfs.
- “ Subtilis (Greg.), Ralfs.
- Actinoptychus excellens, Schumann.
- “ Grundleri, A. S.
- “ Heliopelta, Grun., plentiful.
- “ nitidus, Grev.
- “ undulatus, Ralfs.
- Aulacodiscus Rogersii (Bail.), A. S.
- “ Sollitianus, Norm.
- Auliscus spinosus, Christian.
- Biddulphia Tuomayi (Bail.), Roper.
- Coscinodiscus radiatus.
- “ robustus.
- Craspedodiscus Coscinodiscus, Ehr.
- “ elegans, Ehr.
- Epithemia turgida, Kutz.
- Goniothecium Rogersii, Ehr.
- Grammatophora marina (Lyngb.), Kutz.
- Hemiaulus Polycistnorum, Ehr.
- Hercotheca mammilaris, Ehr.
- Hyalodiscus subtilis, Bail.
- Melosira sulcata, Ehr.
- Pinnularia permagna, Bail.
- “ viridis, Ehr.
- Plagiogramma tessellatum, Grev.
- Sceptroneis caducea, Ehr.
- Stephanogonia Actinoptychus, Ehr.
- Stephanopyxis turris (Grev.), Ralfs.

Surirella splendida, Kutz.

Triceratium acutum, Ehr.

“ *obtusum*, Brightw.

“ *Kainii*, Schultze.

“ *semicirculare*, Brightw.

“ *spinosum*, Brightw.

Xanthiopyxis panduræformis, Pant.

I.

SEC. 2.—RECORDS OF WELLS IN CRETACEOUS STRATA.

ARTESIAN WELL AT WATER WITCH, AT THE BASE OF THE HIGHLANDS OF THE NAVESINK.

Elevation, about 5 feet; diameter, 6 inches; depth, 224 feet.
Overflows at the surface.

E. S. Atwood, treasurer of the Water Witch Club, furnishes the record below of a well put down for the club by Uriah White the present year, and states that the well “is only a few feet above tide and is right alongside of the New Jersey Central (Southern Branch) Railroad track, about three-quarters of a mile west of the Highlands of the Navesink station, and about fifteen rods east of the Water Witch station.”

This well has a depth of 224 feet, and is about ten feet east of a well sunk last year for the same club to a depth of only 142 feet, as noted in last year's (1897) annual report, page 244.

Black marl.....	Surface to 40 feet
Fine white sand, some mica in it.....	30 feet = 70 “
Dark brown clay	20 “ = 90 “
Dark fine sand, <i>with water</i>	45 “ = 135 “
Black clay.....	15 “ = 150 “
Coarse white sand.....	30 “ = 180 “
Black clay.....	5 “ = 185 “
Coarse white sand, <i>with water</i>	39 “ = 224 “

E. S. Atwood states that a test was made for three hours, and that “an average of 100 gallons a minute was pumped, the water standing steadily at about 22 feet below the surface, and quickly filling when the pumping ceased.” He also says, “We pump the water to a tank 275 feet higher up, on top of the hill, and supply the club-house and cottages from it.”

NOTE RESPECTING WELLS IN THE REGION OF THE HIGHLANDS OF THE NAVESINK AND THE PENINSULA OF RUMSON'S NECK.

The following seven well-records have been furnished by Matthews Bros. The wells are west of Seabright, and are mostly on the peninsula between the Shrewsbury and the Navesink rivers. These records, together with those of twenty-nine others reported by the same firm last year*, abundantly demonstrate that there occur beneath the Highlands of the Navesink and the peninsula of Rumson Neck two water-horizons readily accessible. The two horizons are each about 50 feet thick, and are separated by a blue clay only ten to fifteen feet thick. These horizons are clearly below the true marl series, and are entirely within the clay marls or Matawan formation.

ARTESIAN WELL ON RUMSON BLUFF.

Elevation, 14 feet; diameter, 3 inches; depth, 349 feet. Water rises within nine feet of the surface.

This well was also put down by Matthews Bros., who state:

"Early in 1898 we drilled a 3-inch artesian well for Rev. Egan, situation on the Rumson Bluff, about quarter mile west of Seabright. The elevation above tide-level is about 14 feet. The depth of the well is 349 feet, and the water rises to within 9 feet of the surface. This proved to be a very successful well, the supply of pure sparkling water being a continual yield of 94 gallons per minute—a big yield for this size well. The borings were:

- "4 feet clay.
- 14 " brown sand.
- 38 " black sand.
- 36 " marl.
- 4 " cemented shells.
- 3 " colored pebbles.
- 72 " dark-colored sand.
- 14 " white clay.
- 42 " black marl.
- 53 " white sand and wood (*water-bearing*).
- 11 " blue clay.
- 58 " white sand and wood (*water-bearing*).

349 " being the total depth of the well."

* Annual Report, 1897, pages 227 to 243.

ARTESIAN WELL ON RUMSON BLUFF.

Elevation, 15 feet; diameter, 3 inches; depth, 372 feet. Water rises within 18 feet of the surface.

This well was put down by Matthews Bros., who write: "We drilled a well for Mr. Leighton Withers, whose cottage is situated on Rumson Bluff, near Seabright, New Jersey. The elevation above tide-level is about 15 feet. The well is 3 inches in diameter and 372 feet deep. It yields 57 gallons per minute, and the water rises to within 18 feet of the surface. The strata passed through were:

"	9 feet	sand.
4	"	clay.
10	"	brown sand.
31	"	black sand.
43	"	marl.
4	"	shells.
4	"	different colored pebbles.
66	"	dark sand.
22	"	white clay.
41	"	marl.
69	"	white sand and wood.
14	"	blue clay.
43	"	white sand and wood (<i>water-bearing</i>).
12	"	small white gravel (<i>water-bearing</i>).
372	"	total depth."

ARTESIAN WELL ON RUMSON BLUFF, TWO MILES WEST OF SEABRIGHT.

Elevation, 45 feet; diameter, 6 inches; depth, 218 feet.
Water rises within 38 feet of the surface.

This well was put down by Matthews Bros., who write: "We drilled a well for Mr. Lobb, whose residence is situated on Rumson Neck, about two miles west of Seabright. The elevation, above tide-level, is about 45 feet. The well is 6 inches in diameter and gives an abundant supply of water, which has been analyzed several times, and always found pure and very fine for domestic uses. The water rises to within 38 feet of the surface, and the depth of the well is 218 feet. The strata passed through were:

“ 27 feet red sand.	
59	“ marl.
7	“ <i>shells.</i>
5	“ sand.
54	“ marl.
39	“ white sand.
27	“ white sand (<i>water-bearing</i>).
<hr/>	
218	“ total depth.”

ARTESIAN WELL, ONE AND ONE-QUARTER MILES WEST OF
SEABRIGHT, ON RUMSON ROAD.

Elevation, 36 feet; diameter, 3 inches; depth, 387 feet. Water rises within 31 feet of the surface.

This well was put down by Matthews Bros., who write:

“ We drilled a well for Mr. Bloodgood, whose residence is along the Rumson road, about $1\frac{1}{4}$ miles west of Seabright. The elevation above tide-level is about 36 feet. The well is 3 inches in diameter and 387 feet deep. The water rises to within 31 feet of the surface. The strata passed through were :

“ 7 feet brown sand.	
20	“ red clay.
9	“ brown sand.
37	“ red clay and iron ore.
46	“ marl.
4	“ <i>cemented shells.</i>
4	“ colored pebbles.
71	“ dark-colored sand.
19	“ white clay.
42	“ marl.
58	“ white sand.
13	“ blue clay.
57	“ white sand and wood (<i>water-bearing</i>).
<hr/>	
387	“ total depth.”

ARTESIAN WELL NEAR OCEANIC.

Elevation, 15 feet; diameter, $4\frac{1}{2}$ inches; depth, 267 feet.
Water rises within 11 feet of the surface.

Respecting this well the contractors, Matthews Bros., write :

“ We drilled a well at Babies' Hospital, near Oceanic. The elevation above tide-level is 15 feet. The well is 267 feet deep and $4\frac{1}{2}$

inches in diameter ; the water rises to within 11 feet of the surface. This well proved to be a very good one. The supply was large and the water excellent for drinking. The strata passed through were :

“ 35 feet	sand.
17 “	clay.
11 “	brown sand.
37 “	brown sand and clay.
44 “	marl.
5 “	<i>shells.</i>
3 “	gravel.
57 “	dark sand.
24 “	marl.
34 “	white sand (<i>water-bearing</i>).
<hr/>	
267 “	total depth.”

ARTESIAN WELL NEAR LOCUST POINT, ON THE SHREWSBURY RIVER.

Elevation, 4 feet ; diameter, $4\frac{1}{2}$ inches ; depth, 293 feet.

Natural overflow, 27 gallons a minute.

Pumps continually, 94 gallons a minute.

Matthews Bros., contractors, write as follows respecting this well

“ We drilled a well for Vincent Lamarche, whose summer residence is on the north side of the Shrewsbury river, near Locust Point. The elevation above tide-level is about 4 feet.

“ The well is $4\frac{1}{2}$ inches in diameter, and is 293 feet deep. This well is a very good one, having a natural flow of 27 gallons per minute, and would yield 94 gallons per minute continually without lowering the water to any extent.

“ The strata passed through were :

“ 2 feet sand.
37 “ marl.
9 “ sand.
49 “ sand and marl.
4 “ different-colored pebbles.
64 “ dark-colored sand.
27 “ white clay.
59 “ black marl.
42 “ white sand and wood (<i>water-bearing</i>).

293 “ total depth.”

ARTESIAN WELL ON CLAY-PIT CREEK, ABOUT TWO MILES SOUTH-EAST OF HIGHLANDS OF NAVESINK.

Elevation, 14 feet ; diameter, 3 inches ; depth, 68 feet.

Water rises within 10 feet of the surface.

Matthews Bros. write respecting this well : " We drilled a well for Mr. Yallalee, whose residence is on Clay Pit creek, about two miles southeast of the Highlands of Navesink. The well is three inches in diameter, and is only 68 feet deep ; the elevation above tide-level is 14 feet, and the water rises to within 10 feet of the surface. We found in drilling this well a stratum not found by us in any well ever drilled by us, namely, a water-bearing stratum of heavy gravel 48 feet from the surface, and 20 feet deep ; the water-supply is good and the water pure and good. The strata passed through were—

" 25 feet sand.
11 " clay.
12 " sand.
20 " heavy gravel (water-bearing).
—
68 " total depth."

We would call attention to the mention made by Matthews Bros. of the unique occurrence of the heavy gravel at the bottom of this well, while they had not obtained such gravel from the numerous other wells drilled by them with a surrounding area of about three miles square. It probably indicates a deposit much more recent than the Cretaceous, which undoubtedly underlies the base of this well. The writer would suggest that this gravel and the overlying sand and clay beds probably belong to the Cape May formation.

ARTESIAN WELL AT AVON.

Elevation, 10 feet ; diameter, $4\frac{1}{2}$ inches ; depth, 580 feet.

A four and one-half inch well has been sunk the past year at Avon (formerly Key East), by Uriah White, who says its depth is 480 feet and its pumping capacity 40 gallons a minute. This water-horizon is the same as that reached by the well of the succeeding record at North Spring Lake, both being the equivalent of that at Asbury Park at the depth of 550 feet.

ARTESIAN WELL AT NORTH SPRING LAKE.

Elevation, 20 feet; diameter, 6 inches; depth, 705 feet.

Uriah White writes that during the year he has put down a six-inch well at North Spring Lake to the depth of 705 feet, and that the well has a pumping capacity of 100 gallons a minute. The water horizon reached is the equivalent of that at 550 feet at Asbury Park.

ARTESIAN WELLS AT LAKEWOOD.

No. 1.—At "*The Laurel-in-the-Pines.*"

Elevation, 60 feet; diameter, 6 inches; depth, 606 feet.

Water overflows at the surface 20 gallons a minute.

No. 2.—Put down for A. M. Bradshaw, on Ocean avenue, one-half mile east of the New Jersey Southern Railroad depot.

Elevation, 40 feet; diameter, 3 inches; depth, 625 feet.

Water overflows at the surface 45 gallons a minute.

From Kisner & Bennett we learn that they have put down at Lakewood two wells, for which they furnish the data noted above. The water-horizon of these wells is the equivalent of that at the depth of 550 to 575 feet at Asbury Park.

Through the courtesy of Kisner & Bennett, and of A. M. Bradshaw, we have also received a full and complete series of the borings from the well at the hotel, from a careful study of which we present the record on the next page.

We would call attention to the fact that in the records of this well at Lakewood and of a well at Farmingdale [pages 99 and 100], there are noted the occurrence in association with the marls of the marl series of foraminifera comprised mainly in the genera *Nodosaria*, *Crestellaria*, *Fronicularia*, and *Vittrewebbina*. Those of the first three genera are large forms while the *Vittrewebbina* is much smaller and occurred in chains on the surface of the *Fronicularia*. The forms of *Fronicularia* and *Vittrewebbina* are figured by R. M. Bagg, Jr., in Bull. U. S. Geol. Survey No. 88, Plate II.

In both the Farmingdale and the Lakewood wells the ash-colored clays, constituting Prof. G. H. Cook's ash-marl or middle layer of the upper marl bed, contain *Coccoliths* and *Rhabdoliths*.

This is the second well at The Laurel-in-the-Pines. There are also two wells at the Laurel House, one about 400 feet deep and the other about 600 feet. Some of these wells have been noted in previous annual reports. It is said, there is also another well in the town with a depth currently reported of 700 feet. If so, there are now at Lakewood six deep artesian wells.

ARTESIAN WELL AT FARMINGDALE.

Elevation, 70 feet; diameter, 8 inches; prospected to the depth of 730 feet; finished at the depth of 540 feet.

A well has been drilled at the Dittmar Powder Works, about one mile south of the railroad station at Farmingdale. The work was done by Uriah White, who has kindly furnished a series of the borings to the depth of 540 feet. He, however, informs us that while the well was finished at that depth, the boring had been nevertheless previously prospected to the depth of 700 feet.

From a study of the specimens we make the subjoined record. Large foraminifera, comprising mainly various species of each of the genera *Nodosaria* and *Fronicularia*, and also fragments of *bryozoans* were noticeable at various depths from 210 feet to 320 feet.

In the specimen of marl marked from the depth of 320 feet, there were also a few small fragments of a bivalve mollusk from about midway between the beak and the outer margin. In the absence of the hinge and consequently of the teeth characters, we identify the fragments as probably *Pteropsis* (*Lutraria*) *papyria*, Conrad, (?) the original type specimen of which is in the collections of the Academy of Natural Sciences, and was obtained from the Lower Claiborne division of the Eocene deposits near Claiborne, Ala. After a careful study of the beds in this well and comparison of the borings with those from wells at Lakewood, Asbury Park and Sea Girt and the drawing of a vertical cross-section showing the relation of these wells, we find that upon stratigraphical grounds we shall have to refer the marl in which this fossil was found to near the base of the Middle Marl bed or the Rancocas division of the Cretaceous.

PTEROPSIS (LUTRARIA) PAPYRIA (?) CONRAD.

Exteriorly our fragments of this fossil also resemble the modern *Labiosa canaliculata* Say, of which we have seen specimens collected on the beaches of Cape May county. We cannot, however, find that this *Labiosa* ranges back of Miocene times, and therefore, in the

absence of the teeth and hinge characters, which are decidedly different in the two genera, we think it more probable that our fragments represent more nearly the fossil *Pteropsis*, which may thus have a range somewhat lower than the Eocene. The wrinkles which extend in both these genera from the umbo or beak to the outer margin of the valves and which are much alike in both, are, we think, somewhat finer on our specimens than on Conrad's Eocene type, and more nearly of the same fineness as those on the living *Labiosa*. This character, however, varies, being finer or coarser on different parts of the same valve in both genera.

The thickness, character and succession of the various minor strata in this well correspond very closely at the same depths from the surface with the same strata in the wells at Asbury Park. This well is some 50 feet higher than the wells at Asbury Park; while the latter place is the farther out on the dip of the Cretaceous beds. Fifty feet, therefore, represents the amount of dip between the two localities, the distance between which, along the line of dip, we estimate at about one and one-half miles.

RECORD.					
Orange-yellow sand.....	0 feet to	20 feet.	}	Recent.	
Interval (no specimen).....	20 "	40 "			
Medium-coarse brownish sand.....	40 "	60 "	}	Miocene. (?)	
Interval (no specimen), probably brown clay "Rottenstone" of well-drillers.....	60 "	75 "			
Very sandy greenish clay, large proportion of greensand marl, <i>Nodosaria</i> and other large foraminifera	75 "	110 "			
Ash-white sandy clay quite calcareous—a few greensand grains—numerous <i>Rhabdoliths</i> and <i>Coccoliths</i>	110 "	to 150 "	}	Ash Marl of Prof. Cook.	
Greensand marl with large foraminifera, <i>Nodosaria</i> and <i>Fronicularia</i>	150 "	to 160 "			
Nearly pure greensand marl,	160 "	to 175 "			
Dark micaceous clay.....	175 "	to 190 "			
Greenish-gray sandy clay mixture of greensand-marl and whitish sand ...	190 "	to 210 "	}	Green Marl of Prof. Cook, or lower layer of Upper Marl.	

Shark River
formation.
Eocene.

Manasquan
formation.
Cretaceous.

Upper Marl bed.

Greenish-gray sandy clay, lighter shade than next above; mixture of green- sand marl and ash-color- ed clay, <i>Bryozoa</i> , large fo- raminifera (<i>Nodosaria</i> , etc.), and <i>Echimis</i> spines. 210 " to 235 "	Equivalent of the Bryozoan, Limesand or Upper layer of Middle Marl.	Vincentown Sands. Cretaceous	Middle Marl Bed.
Dull greenish gauconitic sand (marl) with same <i>foraminifera</i> as next above..... 235 " to 260 "			
Nearly pure greensand marl..... 260 " to 290 "			
<i>Echinus</i> spines <i>Bryozoa</i> and <i>Nodosaria</i> at 270 feet.			
Greensand marl with a large proportion white quartzose sand, <i>Bryozoa</i> , <i>Nodosaria</i> , <i>Fronicularia</i> .. 290 " to 300 "	Greensand or Lower layer of Middle Marl.	Rancocas Marl. Cretaceous.	Middle Marl Bed.
Greensand mixed with ash colored clay..... 300 " to 310 "			
Nearly pure greensand marl, somewhat clayey at the base, where occur <i>Bryozoa</i> , <i>Nodosaria</i> and <i>Fronicularia</i> 310 " to 320 "			
Also, at 320 feet, a bi- valve <i>Pteropsis papyria</i> Conrad (see pages 98 and 99.			
Dark greensand marl... .. 320 " to 340 "	Red Sands and Lower Marl.	Monmouth. Cretaceous.	Lower Marl Bed.
Dull gray mixture of quartz sand and a small propor- tion of greensand marl. <i>Shell bed</i> at 360 feet..... 340 " to 375 "			
Micaceous clayey sand..... 375 " to 430 "			
Micaceous sandy clay..... 430 " to 450 "			
Interval (no specimen) probably same as at the corresponding horizon at Lakewood (see page 97), viz., greensand marl..... 450 " to 500 "	Clayey Marls and Sands.	Matawan. Cretaceous.	Clay Marls.
Yellowish quartzose sand.. 500 " to 540 "			

This well was prospected beyond, to the depth of 730 feet, but was afterwards finished with a depth of only 540 feet.

ARTESIAN WELL, SEASIDE PARK.

Elevation, 3 feet; depth, 515 feet. Water overflows at the surface 16 gallons per minute. Temperature, 58 degrees Fahrenheit.

With the opening of the summer season at Seaside Park a well-boring was made at that point to a depth of 515 feet, but completed at the depth of 490 feet. It overflowed at the surface at the rate of 16 gallons per minute. The work was done by Uriah White, who courteously saved for the survey a full series of the borings taken every 10 feet. From an examination of these we present the following record:

Gray sand and clay, with a few <i>diatoms</i> and <i>sponge spicules</i>	10 feet to	20 feet.
Brownish sand described by the driller as "red sand".....	20 "	30 "
Black clay, with vegetable stems; no diatoms observed...	30 "	32 "
Coarse sand and coarse gravel mixed, the pebbles showing Silurian or Devonian corals. This bed contained also oyster and clam shells of recent or living species...	32 "	40 "
"Blue" clay, no micro-organisms.....	40 "	60 "
Brownish-gray clayey sand.....	60 "	80 "
Whitish sand, coarse.....	80 "	87 "
Clay with lignite; no micro-organisms.....	87 "	90 "
Whitish sand (medium).....	90 "	135 "
Brownish sandy clay with lignite, lighter in color at the base.....	135 "	150 "
Whitish gray sand.....	150 "	190 "
Darker micaceous quicksand.....	190 "	200 "
Coarse bluish white gravel.....	200 "	210 "
Dark micaceous clayey sand.....	210 "	235 "
"Brown" clay.....	235 "	240 "
Fine micaceous clayey sand.....	240 "	270 "
Coarse gray sand or fine gravel.....	270 "	285 "
Micaceous sandy clay.....	285 "	295 "
Fine sand with glauconite grains.....	295 "	315 "
Coarse " " " ".....	315 "	340 "
Olive-green marl, glauconite.....	340 "	425 "
Dark green marl, glauconite.....	425 "	465 "
Gray sand, with greensand grains.....	465 "	480 "
Mixture of gravel, clay and greensand (<i>water-bearing</i> from 465 to 490 feet).....	480 "	490 "
Clay prospected from.....	490 "	515 "

This well was finished at the depth of 490 feet by the insertion of a 30-foot strainer so as to draw from the water-yielding sands and gravels between the depths of 465 and 490 feet.

The water-horizon is practically the same as that used by the well at Berkeley Arms, about one mile northward, and noted in the annual reports for 1884, page 127, and 1885, page 133. We cannot yet certainly correlate this horizon with any other of the water-horizons we have heretofore defined. A boring stratigraphically somewhat deeper is necessary in order to learn the exact position of the beds penetrated and of the water-horizon reached by this well. We would, however, tentatively refer it to the 950-foot horizon at Atlantic City, subject to confirmation or otherwise in the future.

Some water was also found in this boring at the depth of 150 feet and again at that of 200 feet.

We regard the beds penetrated by the lower portion of this well as stratigraphically below the Miocene beds encountered by the wells along the coast to the southward, and above those Cretaceous and perhaps Eocene beds met with in most of the wells to the northward.

We may remark that there do not occur in this boring any of the peculiar ash-colored clays containing coccoliths* found in the upper portions of the well-borings in the region about Asbury Park and Belmar, and noted in this report as occurring in similar clays and in similar position in borings at Lakewood and Farmingdale.

ARTESIAN BORING AT TOMS RIVER.

Elevation, 40 feet; depth, 745 feet.

Revision of record in the annual report for 1896.

This boring was made in the year 1888, and was noted in the annual report for the year 1896, page 153. The record then submitted was mainly compiled from notes received from a member of the survey who had been permitted to examine a series of the borings that had been preserved by John P. Haines, for whom the well had been drilled. More recently the writer has also had the opportunity of examining the same specimens, confirming the correctness of the former record as to the facts then stated. Our examination, however, was supplemented with the use of the microscope, which enables us now to present another record more in detail as to the beds and with additional facts respecting microscopic fossil organisms in some of them. This revised record is now submitted, viz.:

* These are microscopic fossils whose nature is not understood, but which are found on the ocean bottoms at the present time.

Orange-yellow and light yellow sand, with two clay seams (one yellow, at 30 feet; one white at 55 feet).....	8 feet to 90 feet.	
Brownish sand, with coarse gravel.....	90 " " 165 "	} Miocene. ?
Some lignite at 162 to 165 feet.		
Gray sand.....	165 " " 255 "	
Gray sand, with admixture of probably about 40 per cent. of glauconite grains or greensand.....	255 " " 365 "	} Age (?)
Green clayey marl, with greensand grains and a little <i>comminuted shell</i> , not identifiable.....	365 " " 480 "	
Ash Marl, with <i>coccoliths</i> throughout.....	480 " " 522 "	
Ash Marl, with greensand grains.....	522 " " 620 "	} Age (?)
Greenish Clay, with very considerable pro- portion of greensand, darker than the Ash Marls above.....	620 " " 745 "	
<i>Coccoliths</i> observed at 660, 665 and 680 feet. Specimen at 745 feet a nearly pure greensand marl.		

DUG WELL ONE-QUARTER OF A MILE SOUTHEAST OF IMLAYSTOWN.

Depth, 60 feet.

F. C. Price has kindly furnished the survey with a full series of specimens taken every few feet from a dug well one-quarter of a mile southeast of Imlaystown. The location is on the belt marked on the colored geological map of the State as underlaid by the Middle Marl bed.

From an examination of the specimens we make the following record :

Surface soil.....	8 feet.	} Cretaceous.
Yellow sand.....	8 feet to 14 "	
Yellowish marly sand.....	14 " " 22 "	
Green marl at.....	22 "	
Black marl at.....	34 "	
Olive colored marl at.....	42 "	
Fossil mollusks at.....	41 feet to 42 "	
Olive colored marl at.....	42½ "	
Olive colored marl at.....	45 "	
<i>Terebratulina hartani</i> Say, at.....	45 "	
Crust with <i>Ostrea</i> and other fossil mollusks at.....	48 "	
Green earth at.....	55 "	
Green earth at.....	60 "	

ARTESIAN WELL NORTHWEST OF MOUNT LAUREL.

Elevation, 40 feet; diameter, 3 inches; depth, 197 feet.

Water rises within 34 feet of the surface.

During the summer a three-inch well was bored by W. C. Barr on the Leworthy farm, on the upper road from Moorestown to Mount Laurel, about two and a quarter miles southeast of the former place.

The depth of the well is 200 feet, the top of the water-bearing sand being found at 197 feet.

The water-horizon is that which we have named the Sewell water-horizon,* and is the same as that developed last year at Mount Laurel on the Shreeve farm, one and one-quarter miles nearly due southeast, and which was there met with at the depth of 304 to 306 feet. Allowing for the difference in elevation between the two wells of 30 feet, these data indicate a dip of the strata of about 70 feet per mile, which is, we apprehend, rather greater than the average dip of the beds and is probably only local.

The same succession of beds of black and of greenish clays belonging to the clay marls were passed through as at Mount Laurel. In the clays were found a few nodules containing a few casts of Ripley fossils, but the rich development of these fossils with the shell substance preserved as occurred in the Shreeve well† at the base of Mount Laurel was entirely wanting here.

W. C. Barr furnished a series of the borings from this well and a record of the thickness of each bed.

That record, with the introduction of geological notes of our own, is as follows:

Commenced on the bottom of a dug well				
at the depth of.....	12 feet =	12 feet.		
Green marl	10 "	= 22 "	} Matawan Cretaceous.	
Coarse sand, almost gravel, with lignite....	18 "	= 40 "		
Black clay.....	105 "	= 145 "		
Green clay, with <i>fossiliferous</i> pyritous iron- stone nodules.....	23 "	= 168 "		
Black clay, with casts of <i>fossils</i> in pyrite....	23 "	= 191 "		
Green clay.....	6 "	= 197 "		
Sand, <i>water-bearing</i> , the <i>Sewell water-</i> <i>horizon</i>	3 "	= 200 "		

* See page 66.

† Annual Report, pages 262 to 264.

The surface has an elevation of 40 feet, and the water rises within 34 feet thereof.

At the base of the Clays, just above the water-sand, was found a fragment of a flat bone, possibly part of the plastron of a Cretaceous turtle.

FOUR TEST WELLS AT WEST PALMYRA.

Elevation, high-tide level; depths, 30 to 33 feet and 46 feet. Bored for the Palmyra Filtrated Water Company, prospectively to supply water filtered directly from the river.

The lower or 46-foot horizon is in gravel of the Raritan Cretaceous age, while the upper or 30-foot horizon is in a clean, clear bed of medium to moderately coarse gravel of much more recent age, but what that age is the writer is not at present prepared positively to say, beyond the fact that it *may* be either the Trenton gravel or the Pensauken, and is not older than the latter.

These wells were reported more fully last year.* An egregious error, however, slipped into print by which we were made to state the capacity of the company's proposed water basins at the one one-thousandth of the true figures.

In justice to them we now reinsert the paragraph referred to printed as it should then have appeared, adding a line or so at the bottom.

The Palmyra Filtrated Water Company is an incorporated company, whose plan is to sink into the gravels revealed by these wells a series of eight basins, with a combined capacity of 2,000,000,000 gallons, into which basins the water of the Delaware river may be allowed to percolate by filtration, which it will probably do, since the river has cut its channel in these gravels, and has a depth of 30 to 40 feet between this point and the opposite shore. A full series of borings from each well are in the office of the company. This horizon is higher than the two horizons utilized at Morris Station for Camden water-supply.

ARTESIAN WELLS FOR CAMDEN WATER-SUPPLY, AT MORRIS STATION.

100 or more wells. Depths, 50 to 125 feet.

Since about the year 1853 the city of Camden has taken its supply of water from the eastern or Jersey Channel of the Delaware river, which flows between Petty's Island and the main land of the township

* Annual Report, 1897, pages 276 to 278.

of Stockton. This channel forms a bend or cove back from the main course of the river, into which cove Cooper's creek empties, the pumping station being located at Pavonia, a short distance northeast of the mouth of the creek. Owing to the gradual accumulation of influences, which we need not here enumerate, but which were adverse to the purity of the water, the supply has become of late years quite unsatisfactory.

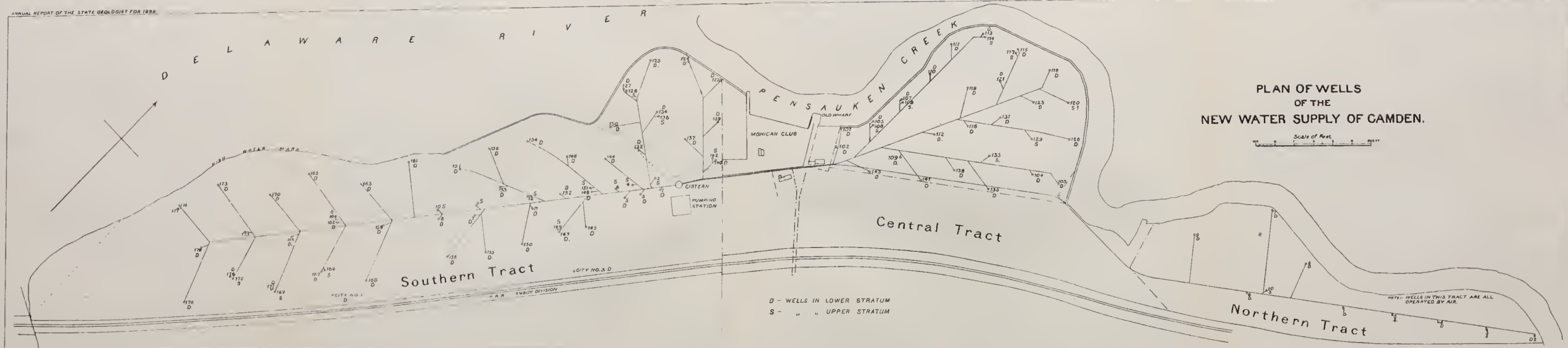
After some agitation and the discussion of various methods for improving the water-supply, a number of test wells were sunk north of Delair, near to and on the westerly side of the Camden and Amboy Division of the Pennsylvania Railroad. These test wells proved the existence at the base of the Raritan or plastic clay division of the Cretaceous deposits, of beds of gravel yielding an abundance of water of good quality. It was therefore resolved to obtain a supply from these gravels by means of artesian wells. For this purpose there was purchased a strip of meadow land containing nearly one hundred ($94\frac{3}{4}$) acres north of Delair, and between the river and the railroad. Lengthways this tract extends from the mouth of Pochuck creek northward to the mouth of the Pensauken.

Near Morris Station, and midway of the tract, there has been established a pumping station, while, distributed over the area, there have been sunk during the years 1897 and 1898 one hundred and one (101) artesian wells. (See Plan, Plate IV.)

The contractor for the entire plant was the Hon. George Pfeiffer, to whose courtesy and appreciation of the interests of the survey, as well as to a like courtesy and appreciation on the part of Wm. E. Boardman, C. E., in charge of the work, we are especially indebted for much information from time to time as the work progressed, and for permission to copy complete records of strata from separate vertical sections drawn accurately to scale at the time of the completion of each well, and also for the final presentation to the survey of very full and separate series of the borings from nearly all of the wells. These have been arranged in the collection at Trenton.

As will be seen by reference to the plan, Plate IV, the area over which the wells are distributed is naturally divisible into three tracts, designated thereon as northern, central and southern tracts.

The acreage and the number of wells in each tract, excluding two wells not connected with the system, are as follows :



	Acres.	No. of Wells.
Northern tract,	17.25.....	10
Central tract,	18.93.....	30
Southern tract, 58.57 {	Northern section.....	20
	Southern section.....	41
Total.....	94.75	101

The two wells noted as not connected with the system are marked on the map, City No. 1 and City No. 3. They are two of four test-wells put down in 1896, and were reported in the Annual Report for that year, pages 103-104. These two test-wells will not be included in any future figures referring to the number of wells.

The numbers attached to each well on the plan are those that were successively given them as they were put down in the order of time, and must not be mistaken for depths of the wells in feet.

Twelve of the wells were drilled by Kisner & Bennett, the hydraulic or washout process being used.

These are, all of them, in the southern tract, and are numbered 1 to 12. They are located near the central pipe, with which are connected all of the lateral pipes leading on either side from the wells on the outer edges of this tract.

All the remaining wells of the entire area, eighty-nine in number, were sunk by the Cook Well Co., of St. Louis, the ordinary drill and sand-bucket being used. They are numbered from 101 upwards, excepting those in the northern tract, which are separately numbered 1 to 10.

The wells may be classed according to depth into shallow and deep ones; these are marked on the plan with the letters S. and D. The shallow wells are from 50 to 70 feet in depth, and the deep ones from 90 to 125 feet. Both classes of wells draw their supply from sands and gravels entirely within the Plastic clays or the Raritan division of the Cretaceous, which division constitutes the basal beds of the southern or coastal plain portion of the State. The water-horizons of these wells are the lowest in the group of water-horizons, which we have designated on page 66 as constituting the Raritan group.

The depths of the wells are as follows. Those in each tract are separately enumerated; they are arranged in the order of their occurrence on the dipping planes of the Cretaceous beds, whose dip is to the southeast.

Northern Tract.

The wells of this tract were prospected a few feet into rock, but were afterwards finished with a total depth a few feet above the rock. The depths given are those in which they were prospected into the rock :

Wells.	Depths in Rock.	Wells.	Depths in Rock.
No. 1.....	128 to 131 feet.	No. 6.....	123 feet.
" 2.....	109 " 113 "	" 7.....	122 to 125 "
" 3*.....	111 " 118 "	" 8.....	121 " 122 "
" 4.....	111 " 115 "	" 9.....	103 " 106 "
" 5*.....	116 " 118 "	" 10*.....	100 "

Central Tract.

Wells.	Depths.	Wells.	Depths.
No. 101.....	100 feet.	No. 116.....	99 feet.
" 102.....	104 "	" 117.....	65 "
" 103.....	99 "	" 118.....	98 "
" 104.....	96 "	" 119.....	100 "
" 105.....	103 "	" 120.....	83 "
" 106.....	52 "	" 121.....	95 "
" 107.....	95 "	" 123.....	99 "
" 108.....	50 "	" 126.....	98 "
" 109.....	93 "	" 129.....	72 "
" 110.....	99 "	" 131.....	101 "
" 111.....	101 "	" 133.....	71 "
" 112.....	90 "	" 135.....	96 "
" 113.....	101 "	" 138.....	90 "
" 114.....	78 "	" 141.....	110 "
" 115.....	102 "	" 143.....	93 "

Southern Tract, Northern Section.

Wells.	Depths.	Wells.	Depths.
No. 122.....	108 feet.	No. 137.....	115 feet.
" 124.....	104 "	" 139.....	113 "
" 125.....	113 "	" 140.....	114 "
" 127.....	97 "	" 142.....	59 "
" 128.....	58 "	" 144.....	124 "
" 130.....	110 "	" 145.....	98 "
" 132 in rock to†.....	159 "	" 146.....	96 "
" 134.....	104 "	" 147.....	116 "
" 136.....	51 "	" 148.....	111 "

* Wells Nos. 3, 5 and 10, Northern tract, though bored to the depth above stated, were each subsequently finished with a depth of only about 50 feet.

† This well, No. 132, was afterwards finished with a depth of only 110 feet.

Wells.	Depths.	Wells.	Depths.
No. 149.....	54 feet.	No. 2.....	70 feet.
" 150.....	104 "	" 3.....	101 "
" 151.....	61 "	" 4.....	67 "
" 152.....	128 "	" 5.....	113 "
" 153.....	123 "	" 6.....	63 "
" 154.....	116 "	" 7.....	105 "
" 155.....	113 "	" 8.....	112 "
" 156.....	111 "	" 9.....	69 "
" 157.....	103 "	" 10.....	62 "
" 158.....	123 "	" 11.....	109 "
" 161.....	100 "	" 12.....	64 "
" 1.....	106 "		

Southern Tract, Southern Section.

Wells.	Depths.	Wells.	Depths.
No. 159.....	116 feet.	No. 170.....	83 feet.
" 160.....	125 "	" 171.....	123 "
" 162.....	112 "	" 172.....	60 "
" 163.....	98 "	" 173.....	81 "
" 164.....	58 "	" 174.....	118 "
" 165.....	96 "	" 175.....	59 "
" 166.....	68 "	" 176.....	99 "
" 167.....	108 "	" 177.....	50 "
" 168.....	100 "	" 178.....	114 "
" 169.....	62 "	" 179.....	103 "

All of the wells are furnished at the bottom with strainers. These, in the wells put down by Kisner and Bennett, are of galvanized iron pipe with $\frac{3}{8}$ -inch holes and are covered on the outside with brass cloth. These strainers vary from 30 to 40 feet in length.

The wells sunk by the Cook Well Co., of St. Louis, Mo., are furnished with Cook well-strainers, each 24 feet long. These have parallel slots about one-quarter of an inch apart arranged around the circumference of the tube. These slots are V-shaped and are wider on the inside than the outside.

Adjacent to the pumping-station there is a receiving-well 30 feet in diameter and 35 feet in depth.* This well is covered with a conical roof, and into it flows, by means of four systems of pipes, with lateral connections, the water from all the wells. The water from the northern tract, which is 4,000 feet distant, is lifted by means of compressed air, while from the other three tracts the water is syphoned.

* From the bottom of this well two artesian wells, not noted in the previous enumeration, were sunk to the depths of 110 feet and 129 feet from the surface of the ground. These flow directly into the receiving-well. Two iron pipes, three feet in diameter, were also sunk to the depth of six feet from the bottom of the receiving-well. These have double brass-cloth screens across their tops, set flush with the concrete which covers the floor of the large well.

From the receiving-well the water is forced to the city, first through a 36-inch main a little over 19,000 feet in length, and then by a 30-inch main nearly 13,000 feet in length to a new iron stand-pipe 30 feet in diameter and 110 feet in height which is situated on elevated ground in South Camden, on Pear street, near Mt. Ephraim avenue.

We have been furnished with the following statement, taken from a communication made by Chas. G. Darrach to L. E. Farnham, city engineer. It shows the producing capacity of these wells each 24 hours on the occasion of the tests mentioned :

	By Pump. Gallons.	By Weir. Gallons.
Average of seven days' test, May 26th to June 1st, 1898...	20,249,287	19,903,024
Average of 23-day test, July 2d to July 24th, 1898.....	19,813,548	19,474,736
Average of 15-day test, December 19th, 1898, to January 2d, 1899	19,563,332	19,228,799
Average accurate test, January 7th to January 8th.....	19,363,000	19,031,375

Before entering the Cretaceous water-bearing strata there was invariably penetrated a greater or less thickness of the whitish plastic clays peculiarly characteristic of the Raritan beds.

Between the water-bearing strata of the shallow and those of the deep wells we have not been able, after a careful study and the plotting of vertical sections, to make out any well-defined and continuously connected clay-bed; there are, however, many beds of clays between the two horizons which vary in color, being either white, red or yellow. In thickness they measure from a few inches to ten feet or more. These clay-beds seem to the writer to probably be lenticular in shape and to be interbedded at varying depths between the more open sands and gravels, and to be more or less limited in extent so that they cannot be traced continuously across the sections of any great number of wells.

The area over which the wells are distributed is nearly level and its surface about at tide level, some portions being protected from overflow by means of dykes.

The underground structure, as recorded by the borings, is comparatively simple, and consists, over most of the area, mainly of two divisions—an upper one of sands and gravels, of comparatively quite recent date, to a depth of from 20 to 25 feet, and a lower one of much greater age (the Cretaceous), consisting of comparatively thin beds of white, yellow and sometimes red clays, and thicker ones of more or less open sands and gravels. This is the division from which the wells draw their supply. It rests upon the micaceous rock of the Philadelphia belt, which rock occurs a short distance below the bottoms of

the wells of the deeper series, as was learned from a few of the borings, which were prospected beyond the base of the lowest water-horizon.

There seems some evidence, on inspection of the samples of the borings, that the upper division above noted is again divisible into two phases, especially in the Central tract. Overlying the sands and gravels of this upper division, over almost the entire area, there is a thin layer four to five feet thick of alluvium or marsh mud.

In the Northern portion bordering upon the Pensauken creek, this alluvium or mud becomes much thicker, ranging from 25 to 40 feet in depth. This great depth of marsh covers all of the Northern tract and the outer or northern half of the Central tract, viz., that portion within the bow-shaped bend of creek that may be seen by reference to the plan (Plate VI). The three outer wells, Nos. 122, 124 and 125, of the Central tract, also show an increase in thickness of marsh deposit, the depth in these wells ranging from 9 to 15 feet.

Where the marsh is 30 to 40 feet in depth, it rests directly upon the Cretaceous beds, the sands and gravels of the previously described upper division being wanting, having probably been removed by stream erosion.

This shows the amount of geologically recent sediment that has been for very many years gradually accumulating in and filling up the drainage channel at the mouth of the Pensauken.

Microscopic examination shows that this marsh contains everywhere and at all depths certain single-celled minute plant organisms, known as diatoms. These have a siliceous box-like skeleton, which, on account of its indestructible nature, has been preserved.

By chemical and mechanical methods separate preparations were made of material from one of the wells in the northern tract, showing the diatoms which occur at the respective depths of 10 feet, 33 feet and 34 to 41 feet.

At all three of these depths there was found a mixture of fresh water and marine diatoms, the marine forms being more abundant, and perhaps preponderating, in the preparation from the two lower depths.

The depth of the diatom-bearing marsh mud in those wells in which it has more than a few feet of thickness is as follows :

Northern Tract.

Wells.	Depth of Marsh.	Wells.	Depth of Marsh.
No. 1.....	30 feet.	No. 6.....	40 feet.
" 2.....	30 "	" 7.....	37 "
" 3.....	38 "	" 8.....	41 "
" 4.....	36 "	" 9.....	35 "
" 5.....	36 "	" 10.....	Not learned.

Central Tract.

Wells.	Depth of Marsh.	Wells.	Depth of Marsh.
No. 113.....	30 feet.	No. 121.....	38 feet.
" 114.....	30 "	" 123.....	40 "
" 115.....	28 "	" 110.....	42 "
" 117.....	28 "	" 119.....	38 "
" 118.....	27 "	" 126.....	36 "
" 111.....	30 "	" 131.....	18 "
" 120.....	25 "	" 129.....	12 "

Southern Tract, Northern Section.

ON THE MARGIN OF PENSANKEN CREEK.

Depth of Marsh in Wells.

No. 124.....	12 feet.	No. 122.....	7 feet.	No. 125.....	15 feet.
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We append the records of two wells, one of which is No. 132, in the northern end of the Southern tract, near the pumping station, and the other is well No. 8, in the Northern tract. From the latter well specimens of the marsh mud were taken every foot. It is upon the microscopic examination of these that we base what we have already written about the diatoms contained therein.

RECORD WELL NO. 132, NEAR THE PUMPING STATION.

4 feet marshy top soil.....	0 feet to	4 feet.	} Age (?)
6 " sand.....	4 " "	10 "	
16 " gravel.....	10 " "	26 "	
11 " white sand	26 " "	37 "	
9 " white clay.....	37 " "	46 "	
7 " white sand	46 " "	53 "	
2 " fine yellow gravel.....	53 " "	55 "	
5 " white clay.....	55 " "	60 "	
3 " white sand.....	60 " "	63 "	
9 " white clay.....	63 " "	72 "	
8 " yellow gravel.....	72 " "	80 "	
3 " white sand.....	80 " "	83 "	
1 " gravel	83 " "	84 "	
11 " fine white gravel.....	84 " "	95 "	
1 foot white clay	95 " "	96 "	
2 feet gravel.....	96 " "	98 "	} Raritan Cretaceous.
2 " coarse white sand.....	98 " "	100 "	
3 " coarse yellow sand.....	100 " "	103 "	
3 " yellow gravel.....	103 " "	106 "	
7 " coarse gravel.....	106 " "	113 "	
5 " pink clay.....	113 " "	118 "	
4 " blue clay.....	118 " "	122 "	
2 " gravel	122 " "	124 "	
11 " blue clay.....	124 " "	135 "	

3 feet gray sand.....	135 feet to 138 feet.	} Raritan Cretaceous.
2 " yellow clay.....	138 " " 140 "	
6 " green clay.....	140 " " 146 "	
13 " blue clay.....	146 " " 159 "	
1 foot soft disintegrated micaceous rock.....	159 " " 160 "	
Hard rock below this depth.		

RECORD OF WELL NO. 8 IN THE NORTHERN TRACT.

Mud, <i>fresh water and marine diatoms</i>	Surface to 21 feet.	} Recent.
Muddy sand, <i>fresh water and marine diatoms</i> ..	21 feet to 23 "	
Mud, <i>fresh water and marine diatoms</i>	23 " to 33 "	
Muddy sand, <i>fresh water and marine diatoms</i> ..	33 " to 36 "	
Mud, <i>fresh water and marine diatoms</i>	36 " to 41 "	
Muddy sand and gravel.....	41 " to 43 "	} Raritan Cretaceous.
Coarse, clean gravel and pebbles.....	43 " to 50 "	
Clean, coarse gravel, without large pebbles,	50 " to 53 "	
White sandy clay, with yellow streak.....	52 " to 55 "	
Mushy white sand.....	55 " to 60 "	
Clean, coarse gravel.....	60 " to 62 "	
White clay.....	62 " to 65 "	
Clean, white coarse gravel.....	65 " to 116 "	}
Yellow clay.....	116 " to 121 "	
Rock.....	121 " to 122 "	

ARTESIAN WELLS ON THE DELAWARE RIVER, FOOT OF TIOGA STREET, PHILADELPHIA.

Elevation, 10 feet; diameter, 8 inches; depth, 65 feet.

Water rises within a few feet of the surface.

Five wells have been put down at the United Gas Improvement Company's works at the foot of Tioga street, Philadelphia, the location being slightly north of west of Fish House station, N. J.

The strata penetrated were similar in each of the wells, except that the marsh mud layer was deeper in the wells nearest the river.

Thomas B. Harper put down some of these wells and kindly furnished a full series of the borings from one near the river. After an examination of the same we are able to present the following record. The wells were put down by the use of the drill and sand-bucket, which permits the preservation of specimens that show the exact nature of material passed through :

Yellowish, loamy clay, &c., made ground.....	5 feet =	5 feet	
Brownish, loamy clay, probably also made ground.....	5 "	= 10 "	
Black clay, a marsh mud, specimens at 15 and 20 feet, both contained <i>Diatoms</i> and <i>sponge</i> <i>spicules</i>	15 "	= 25 "	} Quite recent geologically.
Brownish clay, a very few <i>sponge spicules</i>	2 "	= 27 "	
Gravel.....	3 "	= 30 "	
Yellowish mixture of clay and gravel.....	20 "	= 50 "	
Yellowish very coarse gravel.....	5 "	= 55 "	
Finer yellow gravel, some clay.....	10 "	= 65 "	
Water at the base.			

THREE BORED WELLS AT AN ICE PLANT, GLOUCESTER, N. J.

Elevation, 10 feet (?); diameter of each, 3 inches ; depth, 84 to 88 feet.

George E. Leach informs us that he has bored three wells at an ice plant in Gloucester City. Each well has a diameter of 3 inches ; their depths vary from 84 to 88 feet. These wells draw from one of the Raritan group of water-horizons.

BORED WELL, THREE AND ONE-HALF MILES SOUTHWEST OF PAULSBORO.

Depth, 28 feet.

Seth Roberts writes that he has put down a well for E. G. Miller on a farm three to three and a half miles southwest of Paulsboro. He furnishes the following record :

Commenced in bottom of old well; depth.....	20 feet.
Slimy reddish sand.....	2 feet = 22 "
Black clay or mud, 4 to 6 feet, say.....	6 " = 28 "

The last stratum of the above record probably represents the Matawan or clay-marl division of the Cretaceous.

ARTESIAN WELL AT FORT DELAWARE.

Elevation, about tide-level ; depth, 390 feet. Water rises above the surface.
Flows at low tide, 50 gallons a minute. Flows at high
tide, 75 gallons a minute.

A well has been put down for the United States government to the north of Fort Delaware, on Pea Patch island in the Delaware river, midway between Ferris Point, Lower Penns Neck, N. J., and Dela-

ware City, Del. The work was done by J. H. K. Shannahan, who has furnished the data tabulated above and also the information which we present in the form of a record, as follows :

Black clay or mud surface to.....	100 feet
Gravel and water, several feet, say.....	100 feet to 110 "
No record to.....	146 "
' Good sand " and some water.....	146 feet to 163 "
Record missing.....	163 " 343 "
Fine white sand.....	343 " 374 "
Coarser sand and gravel with water.....	374 " 390 "

This well draws from one of the Raritan group of water-horizons.

ARTESIAN WELL AT MIDDLETOWN, DEL.

Elevation, about 40 feet. Prospected to the depth of 698 feet.

Finished to draw water from the depths of 535 feet and from 660 to 686 feet.

In the annual report for 1896, page 137, there are reported several borings made at Middletown, Del., one of which reached the depth of 552 feet. J. H. K. Shannahan writes that he has since then bored another well to a greater depth, of which he furnishes the following data, viz :

Material, the same as in former well, to the depth of 552 feet
No rock, however, at this depth, as in the former well,
showing, as the well-driller thought, that said " rock was a
boulder."

Clay.....	6 feet = 558 "
Sand.....	2 " = 560 "
Red clay.....	3 " = 563 "
White clay	17 " = 580 "
Red clay.....	7 " = 587 "
Another " boulder " and very hard red clay.....	2 " = 589 "
Light lead-colored clay.....	66 " = 655 "
Sand with water.....	31 " = 686 "
Red clay.....	12 " = 698 "

This well was furnished with two screens so as to draw water from the depth of 535 feet, and from the entire interval between the depths of 660 to 686 feet.

This and former borings demonstrate that there are at this point a number of water-horizons, as follows :

Water-horizon at 88 feet.....	= Marlton horizon
" " " 475 to 495 feet.....	} = Group of Raritan horizons
" " " 517 " 535 "	
" " " 660 " 686 "	

ARTESIAN WELLS AT AND NEAR ROCK HALL, MD.

No. 1, at Rock Hall; depth, 175 feet. Water rises nearly to the surface; temperature, 52°.

No. 2, at Rock Hall; depth, 345 feet. Water overflows; temperature, 58°.

No. 3, at Rock Hall; depth, 325 feet.

No. 4, near Rock Hall, at Gray's Inn creek; depth, 350 to 400 feet.

Unique diatom bed at Rock Hall at the depth of 21 to 130 feet, but does not occur at Gray's Inn creek.

We learn from correspondence with A. P. Sharp, of Baltimore, Md., that during the past three years there have been drilled three wells upon his property at Rock Hall, Md., on the eastern shore of Chesapeake Bay, and a fourth well two miles southeastward, on Gray's Inn creek.

Well No. 1 has a depth of 175 feet and probably draws from the equivalent or continuation southward of the Marlton water-horizon of New Jersey, while Nos. 2, 3 and 4 probably draw from the Sewell horizon, which occurs at the top of the plastic clays or Raritan division of the Cretaceous.

Through the appreciative interest felt by A. P. Sharp in geological science we have been furnished by him, as each well went down, with a greater or less number of specimens of the borings. From Well No. 3, however, which was put down the present year, the series received was very full. After an examination of this set, and careful reading of our correspondent's letters, and some study of Prof. W. B. Clark's geological map of Maryland in Vol. I of the Maryland Geological Survey, we present the following geological record for the wells at Rock Hall. The well at Gray's Inn creek is slightly different, as will be noted beyond:

RECORD WELLS NOS. 2 AND 3.

	Thickness.	Total depth.	
Surface sand and clay.....	10 feet =	10 feet	} 28 feet. Columbia.
Tough blue clay.....	8 " =	18 "	
Gravel with unsatisfactory water.....	3 " =	21 "	

Blueish clay, contains a mixture of sponge spicules and of <i>fresh-water</i> and <i>marine diatoms</i> , among the latter a unique form <i>Polymyxus</i> <i>coronalis</i> , L. W. Bailey (see page 118)	109 feet = 130 feet	} 102 feet. Post Miocene.	} Cretaceous.
Hardpan of shell, gravel and sand.....	2 " = 132 "		
Greenish yellow sand and clayey sand.....	38 " = 170 "	} 90 feet. Rancocas and Monmouth.	
Gray sand, water-horizon of Well No. 1.....	50 " = 220 "		
Equal Marlton water-horizon.			
Very dark sandy clay.....	15 " = 235 "	} 75 feet. Matawan.	
Dark greenish gray sand.....	15 " = 250 "		
Very dark sandy clay.....	15 " = 265 "		
Sand, slightly yellowish.....	10 " = 275 "		
Black micaceous clay.....	20 " = 295 "		
" Hardpan, supposed to be gravel and sand cemented by iron ".....	2 " = 297 "		
White sand, bottom of Well No. 2 and water-horizon of Wells Nos. 2 and 3; probably Sewell water- horizon.....	28 " = 325 "	} 48 feet. Raritan. ?	
White sand, same as above con- tinuation of Well No. 3.....	20 " = 345 "		

In well No. 4, at Gray's Inn creek, the blue clay noted at Rock Hall between the depths of 28 and 130 feet *is said* to have been wanting and that this interval is there occupied by black and green sands which are probably of Eocene age, at least in great part.

Below these Eocene sands the beds penetrated are said by I. A. Harrison, the contractor who bored the wells, to have been the same as in the lower part, that below 130 feet, at Rock Hall, except that the corresponding beds were about 50 feet deeper. The water-bearing sand at Gray's Inn creek occupying the interval at 350 to 400 feet.

Inasmuch as the blue clay at Rock Hall contains a mixture of fresh-water and of marine diatoms, with a small preponderance in numbers of the fresh-water forms, and inasmuch as among the marine diatoms are some species characteristic of beds belonging to a decidedly later period than the Miocene, we incline to the view that this blue clay is decidedly post-Miocene—in *fact* is possibly Pliocene and may even be Pleistocene in age—and that it was deposited in one or the other of these comparatively recent periods on the margin of the Chesapeake at a time when it was cutting its channel across the Cretaceous, Eocene and Miocene deposits which

had been previously laid down, which beds, or at least the Eocene and Cretaceous, had not been removed by the erosion of the channel of the Chesapeake from the Gray's Inn creek locality, while at Rock Hall, both the Miocene and the Eocene seem to have been carried away near the bay by such erosion, and this diatomaceous clay deposited so as to abut against the Eocene and overlie the Cretaceous.

There were, nevertheless, in the assemblage of diatoms a few characteristic Miocene species, but in proportion to the other forms these were few in number. Among them is *Actinoptychus Heliopelta*, Grun, which our previous studies lead us to believe occurs only at the base of the Miocene. We, however, regard the introduction of *A. Heliopelta* and its associated Miocene diatoms as having been contributed by the sediments washed down by erosion from Miocene beds that probably at one time overspread at the locality but at a higher elevation, and which are still found on the higher land to the southward and at no great distance therefrom.

In our studies of the diatom beds of the Atlantic coastal plain, we have met with but one analogous deposit, and that is at Wildwood, N. J., at the depth of 78 to 181 feet.

The Wildwood and the Rock Hall deposits are similar in containing a preponderance of fresh-water forms over marine; both contain *Triceratium favius*, Ehr, which is not found in the Miocene deposits, but occurs only in the more recent beds along the coast, which beds are quite near the surface and are stratigraphically decidedly higher than the Miocene.

Both deposits also contain a rare form *Polymyxus coronalis*, L. W. Bailey, not previously known as occurring fossil, and only known as living at the present time in the mouths of the Para and the Amazon rivers in South America.

From the bed at Wildwood only one specimen of *A. Heliopelta* was seen, although dozens of mounts have been examined by several observers. The scarcity of this form at Wildwood is probably because that place was too remotely distant from Miocene outcrops at the time of the disposition of this bed to draw sediments therefrom.

The borings at Wildwood reveal two decidedly lower diatom beds, both Miocene. One is the great 300 to 400-foot diatom bed of the Atlantic Coastal plain, and was found between the depths of 370 and 793 feet, and the other, a still lower one, at the depths of 1040 to 1060 feet. Of these two beds, only the lower one contained *Helio-pelta*, but it there occurs plentifully.

We therefore regard the Wildwood bed at 78 to 179 feet and the Rock Hall bed at 50 to 130 feet as synchronous in age, though the beds are not continuously connected. The former, we apprehend, was put down in the Delaware River delta, and the latter, as already intimated, was similarly deposited upon the margin of the Chesapeake, and that both of them were, probably nearly coincidentally, laid down in post-Miocene times, when these rivers coursed their way eastward or southeastward over the then elevated, but now submerged, outer portion of the coastal plain, whose shore line was then many miles eastward of its present margin.

As further indicative of a decided post-Miocene age for these two deposits, we will refer to two other species of diatoms common to both, viz., *Campylodiscus Echeineis*, Ehr, and *Stauroneis Phoenicenteron*, Ehr. Both of these are indicative only of quite recent deposits.

The evidence they present the writer has already summed up in a paper* from which we quote as follows :

“Respecting *Campylodiscus Echeineis*, it may be stated that this form has been recorded as living principally in brackish waters the world over, though Prof. C. S. Boyer informs the writer that he has found it in a fresh-water reservoir at Philadelphia, supplied from the Schuylkill river. Though not, however, heretofore recorded, so far as we are able to learn, as fossil, yet the writer has so seen it in a low-level clay from near Buckshutem on the Maurice river, below Millville, N. J.

“On a map of the surface formations of New Jersey, in the annual report of the geological survey of that State for 1897, there is shown a low-lying, nearly level formation on the shores of Raritan bay and thence bordering the Atlantic ocean from Sandy Hook to the Cape May peninsula, which it either entirely covers or nearly so, and thence extending up the Delaware river nearly to Trenton. This low-lying terrace, which is stated in the text to have an elevation of 30 to 50 feet, extends inland along the courses of the following streams: some 20 miles up the Mullica and the Great Egg Harbor rivers, about 25 miles up the Maurice river, and some 10 miles up the Cohansey river. These measurements were made in a direct line from the mouths of the rivers and not by following the winding courses thereof. The surface deposit of this terrace has been named by Prof. R. D. Salisbury the Cape May Formation. He describes it as a ‘thin body of loam, sand and

* Fossil Mollusks and Diatoms from the Dismal Swamp, Va. and N. C., by Lewis Woolman, Proc. Acad. Nat. Sci., 1895, pages 425 to 427.

gravel of lesser age than any' of the surface formations of the State described in the same paper, 'except possibly the drift of the last glacial epoch.' He further says: 'The strict contemporaneity of this formation with the drift of the last glacial epoch is not established, but it is probably at least partly contemporaneous with it, though its later portions may be still younger.' To this formation belong the diatom clays noted in the preceding paragraph as occurring at Buckshutem.

"*Stauroneis Phoenicenteron* has never been seen by the writer in any of the numerous specimens of Miocene diatomaceous clays which he has examined during the past ten years, nor has it, so far as he has been able to learn from consultation of the literature relating to it, been recorded by others as occurring in beds of that age. It has, however, a world-wide distribution in fresh-water deposits of decidedly later age. Thus Ehrenberg, in his *Mikrogeologie*, page 19, notes its occurrence in the following countries, in deposits which the writer would characterize from their position as decidedly post-Miocene and some of them as perhaps post-glacial, viz.: In Sweden, Italy, Prussia, France, Ireland, Saxony, Russia, Terre-del-Fuego, Guatemala and Nova Scotia, and, in the United States, in New Hampshire and Connecticut.

"That the two deposits are probably synchronous in age would further appear probable from the similarity of their position next below the Cape May or surface formation, and that that age is much later than Miocene may be inferred from the fact that the one at Rock Hall lies, as already stated, directly upon the Rancocas division of the Cretaceous, the Miocene itself resting at a higher level upon Eocene beds a few miles southward and eastward; while at Wildwood the top of the great Miocene diatom clay bed occurs nearly 200 feet deeper than the base of the deposit under consideration, or at the depth of 370 feet from the surface."

The following is the list of species of the diatoms in the bed at Rock Hall as identified by Charles S. Boyer. The fresh-water forms are marked F. Those which also occur at Wildwood are marked W. In a letter accompanying the list, he remarks the "*Heliopelta* occurs only in one form, the one with four rays or eight divisions, the variety named by Ehrenberg, *H. Leuwenhoekii*." He also says "From the presence of *Triceratium favus*, *Cymatopleura elliptica*, *Campylodiscus echeneis* and *Polymyxus coronalis*, I should consider this deposit about the same age as that at Wildwood."

	Occurs at Wildwood.	Fresh Water Forms.
<i>Atinoeyclus Ehrenbergii</i> Ralfs.....	W.	
“ <i>undulatus</i> , Ehr.....	W.	
<i>Actinoptychus Heliopelta</i> , Grün, variety <i>Leuwenhoekii</i> , Ehr.....	W.	
“ <i>undulatus</i> , Ehr.....	W.	
<i>Biddulphia laevis</i> , Ehr.		
“ <i>Tuomeyi</i> Bail.		
<i>Campylodiscus echineus</i> , Ehr.....	W.	
“ <i>sp. ?</i>		
<i>Craspedodiscus Coscinodiscus</i> , Grün.....		F.
<i>Cymatopleura Hibernia</i> , W. Sm.		
<i>Cymbella cuspidata</i> , Kütz.....	W.	F.
“ <i>lanceolata</i> (Ehr), Kirchn.....	W.	F.
“ <i>stomatopleura</i> , Grün.....		F.
“ <i>gastroides</i> , Kütz.....	W.	F.
<i>Epithemia argus</i> , Kütz.....		F.
“ <i>turgida</i> , Kütz.....		F.
<i>Eunotia major</i> (W. Sm.), Rab.....	W.	F.
<i>Gomphonema gracile</i> , Ehr.....	W.	F.
<i>Melosira granulata</i> , L. W. Bail.		
“ <i>sulcata</i> (Marina), Ehr.		
<i>Navicula granulata</i> , Breb.		
“ <i>viridis</i> (Nitzsch), Kütz.....	W.	F.
“ <i>nobilis</i> (Ehr.), Kütz.....	W.	F.
“ <i>Hennedyi</i> , (W. Sm.)		
“ <i>silicula</i>		F.
“ <i>acrosphæra</i> , Kütz.....		F.
“ <i>pachyptera</i> , Kütz.....	W.	F.
“ <i>Smithii</i> , Bréb.....	W.	
“ <i>mesolepta</i> , Ehr.....	W.	F.
<i>Nitzschia circumsuta</i> (Bail), Grün	W.	
“ <i>punctata</i> .		
“ <i>Tryblionella</i> , Grün.....	W.	
<i>Podosira maculata</i> .		
<i>Polymyxus coronalis</i> , L. W. Bail.....	W.	F.
<i>Pleurosigena Spencerii</i> (W. Sm.).....		F.
<i>Stauroneis Phœnicenteron</i> , Ehr.....		F.
“ <i>acuta</i> (W. Sm.).....		F.
<i>Stephanopyxis turris</i> , Ralfs.		
<i>Terpsinoe Americana</i> (Bail), Ralfs.....	W.	
<i>Triceratium favus</i> , Ehr.....	W.	

ARTESIAN WELL AT FAIRPORT, VA.

Diameter, 8 inches to 390 feet, then 6 inches to the bottom; depth, 662 feet.

Terebratula harlani, Say, at 640 feet.

Water flows at the surface 75 gallons per minute.

This well is located in Northumberland county, Va., between the Potomac and Rappahannock rivers. As it passes through beds which

are the continuation southeastward of similar, if not identically the same beds as occur in New Jersey, and as certain fossil mollusks common in this State and which therein indicate a definite geological horizon were obtained from the lower portion, we introduce a description of it from information and from specimens courteously furnished by J. H. K. Shannahan, the contractor, who drilled it, and who states that the well was finished at the base with a screen the bottom of which is at the depth of 662 feet. He also says the water appears to be fresh and all right, and flows at the rate of 75 gallons a minute just above the surface, above which he thinks it would rise some 25 feet if the pipe was run up. Several thicknesses of rock, ten to twenty inches through, were encountered between the depths of 400 and 500 feet, while a thickness of six feet of rock was penetrated at 500 feet. Green clay was struck at 590 feet, in which was embedded some flint stone.

At 640 feet was found some sand with much comminuted shells, among which we recognized, without doubt, *Terebratula Harlani* Say.

At 660 feet the water-bearing sand was entered.

Respecting the *Terebratula*, we may add that a few years since the writer obtained this same fossil from the depth of about 840 feet in a boring made at Old Point Comfort.

This fossil in New Jersey, so far as past observation goes, occurs persistently and only at the top of the middle marl bed, and but for some recent stratigraphical work done in Delaware and Maryland by Dr. R. W. Bagg, we should infer that the finding of this fossil in the two wells just noted indicated the continuance southwardly of the Middle Marl bed. Dr. Bagg instanced finding it in outcrops of the Bryozoon lime-sand underlying the Middle Marl at Noxontown mill-pond, Delaware, and in St. George's county, Maryland, in a still higher stratigraphical position, viz., in association with characteristic Eocene oyster and other shells.*

ARTESIAN WELL AT OLD POINT COMFORT AT "THE CHAMBERLIN."

Elevation, 5 feet ; depth, 945 feet.

During the winter of 1895-96 there was bored at Old Point Comfort, Va., at "The Chamberlin," an artesian well to the depth of 945 feet. The work was done by Thomas B. Harper, of Jenkintown,

*American Geologist, December, 1898, Vol. XXII, No. 6, page 370.

Pa, to whose courtesy and care we are indebted for a full series of borings. These were generally taken every ten feet to the depth of 850 feet, below which, while not quite so frequently preserved, they were taken sufficiently often to indicate all but one of the changes in the material passed through. Water was found at the base, which was seen by the writer to overflow abundantly from the end of the casing when it was elevated seventeen feet above the surface which was but a few feet, say not over five, above high tide, the well being located within ten feet or so of the line where the waters wash the beach.

The water, however, from this boring was unfortunately saline, and while it could be used for flushing and for some other purposes, it could not be utilized for cooking or for steam boilers.

After a careful examination and study of the borings, and of notes furnished at personal interviews with the contractor and his foreman in immediate charge of the work, the writer is enabled to present the following stratigraphical record of this well :

Thickness.	Intervals of depths.
10 feet. Surface sand.....	0 feet to 10 feet.
20 " Sand with minute fragments of shell.....	10 " " 30 " Recent.
10 " Dark gray sand, spines of sea urchins, plentiful.....	30 " " 40 " } Miocene?
10 " Sand, lighter in color.....	40 " " 50 " }
10 " Sandy clay with Miocene shells.....	50 " " 60 " Miocene.
30 " Greenish sandy clay.....	60 " " 90 " "
10 " Sandy clay with Miocene shells.....	90 " " 100 " "
20 " Greenish sandy clay, a few shells.....	100 " " 120 " "
10 " Greenish sandy clay, with shells in greater number....	120 " " 130 " "
30 " Fine dark gray sand, sea urchin spines abundant.....	130 " " 160 " "
20 " Dark brownish sandy clay, with shell.....	160 " " 180 " "
100 " Dark greenish clay.....	180 " " 280 " "
Turritella plebia at 190 ft.	
Arca——Sp. ? at 200 ft.	
Pecten——Sp. ? at 270 ft.	
60 " Dark greenish clay, more sandy but without shells....	280 " " 340 " "
190 " Dark greenish clay, not so sandy, still without shells...	340 " " 530 " "

Thickness.		Intervals of depths.	
30 feet	Dark bluish-green <i>diatom- aceous</i> clay.....	536 feet to 560 feet	Miocene.
30 "	Dark clay <i>not</i> diatomaceous...	561 " " 590 "	"
20 "	Dark brownish sandy clay.....	590 " " 610 "	"
50 "	Greenish clayey sand with a large admixture of green- sand grains and some <i>for- aminifera</i>	610 " " 660 "	Eocene.
50 "	Greenish sandy clay with green sand and <i>foramini- fera</i>	660 " " 710 "	"
90 "	Brownish sandy clay.....	710 " " 800 "	Eocene. ?
20 "	Gray sand, mixture of green- sand grains and pure white quartz grains.....	800 " " 820 "	Cretaceous. ?
20 "	Brownish clayey sand, also contains a mixture of green- sand and quartz grains.....	820 " " 840 "	} Cretaceous.
10 "	Calcareous rock crust and pebble conglomerate, with some <i>wood</i> and <i>shells</i>	840 " " 850 "	
55 "	Dark sandy micaceous clay....	850 " " 905 "	
15 "	Fine gray sand.....	905 " " 920 "	
25 "	Coarse gravel, water-bearing..	920 " " 945 "	

In the year 1864 an unsuccessful attempt to obtain water was made nearly adjacent to the location of this well, inside the walls of Fort-ress Monroe, the depth reached being 907 feet.

Since then other unsuccessful attempts to obtain water have been made at points a few miles more or less distant, as at Mill Creek, where a total depth of about 425 feet is believed by the writer to have been reached, (this was reported much deeper,) and also at Back River, where there was attained a depth of 1,172 feet, and at New-
port News, where work was discontinued at the depth of 581 feet. A well was also sunk, a few years since, at Lampert's Point, near Norfolk, which obtained a flow of water, somewhat salty, at the depth of 617 feet.

A record of the well inside the fort, with geological deductions, was published by Prof. W. B. Rogers in "The Virginias," October, 1882, Volume III, pages 151 and 152, and again in the "Geology of the Virginias," 1884, pages 731 to 736. He expresses the view that the base of the Miocene occurs at the depth of 583 feet. On carefully reading Prof. Rogers' paper, it is evident that below that depth he considered that the well successively passed through Eocene and Cre-
taceous beds and entered what he called the Jurasso-Cretaceous.

In three samples of borings from the Chamberlin well, marked respectively with the depths of 50, 90, and 100 feet, there were considerable numbers of Miocene mollusks, more or less comminuted, however, by the drill, but which we, nevertheless, with the assistance of C. W. Johnson, of the Wagner Institute, of Philadelphia, have been able to identify as in the list below. It will be seen by the preceding record that marine shells also occurred between the depths of 100 to 130 feet, and again at 190, 200 and 270 feet. Except that it was possible to identify *Turritella plebeia*, Say, at 190 feet and to make out generically but without species an *Arca* at 200 feet and a *Pecten* at 270 feet, all the shells below the depth of 100 feet to that of 300 feet were so much comminuted by the boring tools as to be entirely undeterminable. No shells were observed in the specimens below 300 feet until the depth of 840 to 850 was reached, where there occurred a few fragments of *Terebratula harlani*, Say, a Cretaceous brachiopod.

The clays were richly diatomaceous between the depths of 530 to 560 feet, and among the diatoms experienced diatomists have recognized a number of forms especially characteristic of the great Miocene diatomaceous clay bed of the Atlantic Coastal plain, and which has beneath the New Jersey beaches a maximum thickness of 300 to 400 feet, and beneath the Maryland-Virginia Eastern shore peninsula a thickness of 400 feet.

LIST OF FOSSILS.

GASTROPIDA.

	Depths.			
<i>Columbella</i> (<i>Anachus</i>), — sp. ?.....	50 feet.			
<i>Cadulus thallus</i> , Conrad.....	50 "	90 feet.		
<i>Dentalium Attenuatum</i> , Say.....	50 "			
<i>Eulima</i> , — sp. ?.....	50 "			
<i>Olivella</i> , — sp. ?.....	50 "			
<i>Scala multistriata</i> , Say.....	50 "			
<i>Turbonella</i>	50 "			
<i>Turritella alticosta</i> , Conrad.....	50 "	90 "	100 feet.	
<i>Nassa acuta</i> , Say.....	50 "			
<i>Ptychosalpinx atilis</i> , Conrad.....		90 "		

LAMELLABRANCHIATA.

<i>Venericardia granulata</i> , Say.....			100 feet.
<i>Cardium laqueatum</i>			100 "
<i>Corbula</i> , — sp. ?.....		90 feet.	
<i>Corbula inæqualis</i> , Say.....	50 feet.		100 "
<i>Cytherea Sayana</i> , Conrad = <i>C. convexa</i> , Say.....	50 "		
<i>Doscinia acetabulum</i> , Conrad.....	50 "	90 "	

Pecten sp. ?.....	50 feet.		
Pecten Madisonius, Say.....		90 feet.	100 feet.
Pecten Jeffersonias, Say.....			100 "
Pectunculus subovatus.....	50 "		
Tellina declivis, Say.....	50 "		
Ostrea subreflexa.....	50 "	90 "	
Lucina crenulata, Conrad.....	50 "		
Yoldia limatula, Say.....	50 "		
Crepidula — sp. ?.....		90 "	
Crepidula fornicata.....	50 "		100 "
Crepidula (Aculeata) costata, Say.....	50 "		
Venus mercenaria, Morton.....		90 "	
Astarte undulata, Conrad.....			100 "

CRUSTACEA.

Balanus proteus.....	90 "
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DIATOMACEA.

Miocene marine diatoms, at.	530 to 560 feet.
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RADIOLARIA.

Foraminifera, at.....	610 to 710 feet.
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BRACHIOPODA.

Terebratula harlani, Say, at.....	840 feet.
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It may be of interest to note that the last named fossil, the Terebratula, also occurs in borings in the writer's possession taken at the depth of 640 feet at Fairport, Va., on the peninsula between the Potomac and Rappahannock rivers. (See Fairport record, pages 121 and 122).

II.

Bored Wells, Mostly in Northern New Jersey.

In Red Sandstone, Gneiss and Other Rocks, and in the Glacial Moraine, mainly in Essex, Hudson, Somerset and Middlesex Counties, and on Staten Island and Long Island, and along the Delaware River.

Sec. 1.—Artesian Wells Reported by Louis L. Tribus, C. E., at Chatham and at Madison, and by Wm. Wallace Christie, C. E., at Rutherford.

ARTESIAN WELLS AT CHATHAM.

One well—Elevation, 188 feet; diameter, 5 inches; depth, 90 feet. Water rose $8\frac{7}{10}$ feet above the surface.

Three wells—Elevation, 188 feet; diameter of each, 6 inches; depth of each, about 90 feet. Water overflowed from each well.

From Louis L. Tribus, C. E., we learn that there were put down for the water-works at Chatham in the year 1897, four flowing wells to a depth in each case of approximately 90 feet, the elevation of the surface being about 188 feet. The diameter of one of these wells is 5 inches and each of the others 6 inches.

The 5-inch well was the first one sunk. Mr. Tribus states that "water was found at several levels during the driving, though not of active flow until about 90 feet depth was reached, when an open gravel was penetrated and a very handsome volume secured, under head sufficient to rise $8\frac{7}{10}$ feet above the surface. It flowed near the surface about 100 gallons a minute."* The following is the record of this well:

* The natural flow of one of the 6-inch wells afterward sunk is stated at 150 gallons a minute.

Soil.....	2 feet = 2 feet.	
Loam and clay.....	10 " = 12 "	
Fine sandy clay.....	6 " = 18 "	
Pure clay.....	4 " = 22 "	
Clay and small stones.....	5 " = 27 "	
Sand and gravel.....	5 " = 32 "	
Clay and sand.....	3 " = 35 "	
Clay, sand and gravel.....	7 " = 42 "	
Fine sand.....	6 " = 48 "	
Coarse sand.....	1 " = 49 "	
Fine sand.....	4 " = 53 "	
Fine sand and coarse gravel.....	5 " = 58 "	
Fine sand.....	4 " = 62 "	
Very fine sand.....	2 " = 64 "	
Fine sand.....	6 " = 70 "	
Sand and gravel.....	3 " = 73 "	
Quicksand.....	1 " = 74 "	
Coarse sand.....	1 " = 75 "	
Clay.....	1 " = 76 "	
Fine gravel.....	4 " = 80 "	{ Water rose 3 feet above the surface.
Coarse sand.....	3 " = 83 "	
Coarse clean gravel.....	7 " = 90 "	{ Water rose 8 7 ft. above the surface.

Mr. Tribus further writes :

" Three six-inch wells were afterwards driven to approximately the same depth into the same water-bearing gravel and have given practically the same results.

" The wells are separated from each other by about 100 feet, so that the combined flow under the same vacuum when pumping is not much less than the aggregate of the individual flows, the effect on each other being very slight.

" The strata of the different wells are very dissimilar until the gravel is reached, showing the curious irregular deposition of the glacial drift in this part of the moraine evidently a little back of its terminus. The boulders encountered in driving were of small size and readily drilled through and broken up.

" No full test of the capacity of the wells has been made, because the response has always been equal to the full demands of the pumps ; the larger engine operating at times at the rate of one million gallons per twenty-four hours.

" Since the flow was first secured in 1897, there has been no indication of any change.

“The surface springs did not seem to be affected by the free flow of the wells [when first put down], nor have they been at all affected since by the operation of the completed plant.”

ARTESIAN WELLS AT MADISON.

One well—Elevation, 192 feet; diameter, 8 inches; depth, 83 feet. Water rises 8 feet above the surface. Overflow, 2 feet above the surface, 400 gallons a minute.

Three wells—Depth, 101, 103 and 148 feet. Water overflows from each.

Louis L. Tribus, C. E., also writes: “Under almost identical surroundings Madison, N. J., two miles west of Chatham, has been for eight years supplied with water from a large dug well, 35 feet deep by 30 feet diameter, the development of some very active springs. The demands in summer have grown beyond its capacity of 250,000 gallons per day, so that an additional supply has become necessary.

“After a couple of experimental tubes were driven, one to 60 feet in depth, failing to secure a flow at that depth, and the other to 42 feet evidently tapping the same stratum that supplied the dug well, an eight inch wrought iron casing with open end and the lowest five feet perforated with a large number of small holes was put down by drilling and driving to a depth of 83 feet, tapping a supply really remarkable. At a point two feet above the surface the flow was over four hundred gallons per minute, and at six feet about one hundred and fifty, coming to rest about eight feet above the ground.

“Three more wells have been driven to respectively 101, 103 and 148 feet. As at Chatham, the different wells passed through quite diverse stratification, but apparently reached the same water-bearing gravels. Each well yields a very handsome natural flow of water.

“These four wells, with the one 42 feet in depth, have been connected with wrought iron suction mains, laid from 7 to 9 feet below the surface, so as to flow into the large dug well from which the water is pumped into the city system.

“Without going to considerable and unnecessary expense, no close measurement of the quantity of flow can be made, but an estimate per 24 hours of one million gallons natural flow into the receiving-well seems very conservative; direct suction or full syphonage would probably double the quantity if needed.”

The following is the record, as furnished by Louis L. Tribus, of the first of the four deeper wells sunk, to wit, to the depth of 83 feet:

Soil.....	2 feet =	2 feet.	
Clay and boulders.....	12 " =	14 "	
Red sand, clay and gravel.....	8 " =	22 "	
Red clay.....	6 " =	28 "	
Hard pan.....	5 " =	33 "	
Sand and gravel.....	8 " =	41 "	{ Water rose to the surface.
Fine brown sand.....	16 " =	57 "	
Reddish clay.....	9 " =	66 "	
Fine sand.....	9 " =	75 "	
Clay.....	3 " =	78 "	
Coarse gravel, with water.....	5 " =	83 "	

ARTESIAN WELL AT RUTHERFORD, N. J.

Elevation, 60 feet; diameter, 8 inches; depth, 202 feet.

Wm. Wallace Christie, C. E., writes as follows respecting this well:

"I beg leave to report a flowing well driven at Rutherford, N. J., for Zahn & Bowly, and furnish the following record:

" Eight-inch pipe down through sand all of quick-sand nature to.....	35 feet.
Red sandstone.....	35 " to 100 feet.
Dark sandstone.....	100 " " 201 " 8 inches.

"Water came within 3 feet 6 inches of the top in October, 1898. In December, 1898, and in January, 1899, it has overflowed."

II.

Sec. 2.—Bored Wells Reported by W. R. Osborne.

The following wells have been kindly reported by W. R. Osborne, who drilled them. We have copied him nearly verbatim, using quotation marks when his exact phraseology has been copied.

BORED WELL ON HILLS BACK OF KRIESHERSVILLE, STATEN
ISLAND, N. Y., FOR MR. DIETZ.

Diameter, 4 inches; depth, 246 feet.

Went through clays and sands to a depth of 246 feet, where the water rose 120 feet and gives a good supply.

BORED WELLS AT THE NEW YORK VULCANIZING WORKS, PERTH
AMBOY.

No. 1 Well prospected to the depth of 230 feet.

No. 2 Well finished at the depth of 135 feet.

Water from No. 2 rises to the surface of the ground 5 feet above tide.

Well No. 1 passed through the following strata as described by W. R. Osborne, whom we quote verbatim:

Usual drift formation sand and clay.....	105 feet = 105 feet
Fine sand with water.....	47 " = 152 "
Very soft red clayey sand, like the red clay overlying red shale.....	78 " = 230 "

This well was abandoned, and a second well of two inches diameter put down to the depth of 138 feet, the top of the water-bearing fine sand being met with at the depth of 104 feet.

BORED WELL NEAR KEASBYS, AT NELS NELSON'S BRICK FACTORY.

Elevation, 40 feet; diameter, 4 inches; depth, 89 feet.

This boring "commenced on top of blue clay, 40 feet above tide, and found water in free sand at 89 feet."

BORED WELL BELOW KEASBYS, ON THE RARITAN RIVER AT THE
STANDARD FIRE-PROOFING COMPANY'S PLANT.

Elevation, 10 or 12 feet; depth, 72 feet or more.

Respecting this well, W. R. Osborne writes that he "found sands and clays to a depth of 60 feet, where was found white sand with a large quantity of water." Under this sand was "12 feet of white

clay to the top of the trap-rock or gneissic formation usually found in this neighborhood ; the well producing water, 50,000 gallons per day, from the 60-foot level." As this report goes to print, a second well, fifty feet from the first, is going down.

BORED WELL AT BONHAMTON, SOUTH OF METUCHEN.

Depth, 52 feet.

"Found water at 52 feet, after drilling through 52 feet of mucky clay and sand."

BORED WELL NEAR BONHAMPTON, AT NEW BRUNSWICK TRACTION COMPANY'S NEW POWER HOUSE.

Diameter, 6 inches ; depth, 208 feet.

"Drilled through gravel to 65 feet, then struck red shale, finding water in the latter formation at 208 feet."

TWO BORED WELLS AT BRUNSWICK DRIVING PARK.

Depths, 61 and 65 feet.

"Found abundance of water in red shale."

BORED WELL AT RUTGERS COLLEGE, NEW BRUNSWICK.

Depth 244 feet.

This well was sunk in "red shale to the depth of 244 feet, when the boring was stopped and water was pumped at the rate of 12 gallons a minute."

THREE BORED WELLS NEAR MIDDLEBUSH.

Two for Mr. J. A. Nugent, depth 112 and 150 feet.

One for Mr. Blakely, depth 100 feet.

Diameter of each well 6 inches.

"All three of these wells furnish an abundance of water, and all are in red shale from near the surface."

BORED WELL AT DEMEREST, ON HILL TOPS BETWEEN¹ WOODBRIDGE
AND RAHWAY.

Diameter 4 inches ; depth 62 feet.

"This well obtains a good supply of water in red shale. The property belongs to Mr. Mason, of Brooklyn, N. Y."

BORED WELL AT METUCHEN FOR THE C. CARTER BELL
RUBBER CO.

Diameter 6 inches ; depth 67 feet.

This well was in "red shale after 30 feet of sand was passed through."

II.

Sec. 3.—Wells Reported by Stotthoff Bros. Mostly in the Red Sandstone Region and in the Limestone and Other Older Rocks to the North, though a Few are Along the Delaware River, Below Easton, Pa.

The following thirty-five wells are reported by Stotthoff Bros. as having been drilled by them the past year :

BORED WELL AT HAMBURG, SUSSEX COUNTY, FOR W. E. ROGERS & CO.

Diameter, 6 inches ; depth, 160 feet.

Started on bottom of old well at depth from the surface of...	60 feet =	60 feet.
Quicksand.....	35 " =	95 "
Hard blue stone.....	65 " =	160 "

Water, 20 gallons per minute at 100 feet from the surface.

BORED WELL AT LAFAYETTE, FOR GILBERT INGERSOLL.

Limestone 36 feet.

Supply, 10 gallons per minute.

BORED WELL AT BALEVILLE, LEHIGH & N. E. R. R.

Sand, gravel and boulders... 53 feet.

Supply, 10 gallons a minute, 29 feet from the surface.

BORED WELL NEAR PHILLIPSBURG, FOR VULCANITE CEMENT CO.

Depth, 300 feet.

Deepened a 200-foot well to 300 feet. Cement rock which we just got through at the bottom into a soft material resembling clay, but of the same color as the cement rock.

BORED WELL NEAR HIGH BRIDGE, FOR CHAS. P. FRALEIGH.

Earth..... 21 feet = 21 feet.
Limestone..... 62 " = 83 "

Supply, 7 gallons per minute.

BORED WELL AT LAKE VIEW FOR P. R. LINDSAY.

Distance to rock..... 27 feet = 27 feet.
Red sandstone..... 46 " = 73 "

Supply, 2 gallons per minute.

BORED WELL AT PASSAIC FOR BOTANY WORSTED MILLS.

Sand, clay and quicksand..... 90 feet = 90 feet.
Red sandstone..... 312 " = 402 "

Supply, 200 gallons per minute at 97 feet from the surface.

BORED WELL AT PASSAIC FOR DR. A. C. PEDRICK.

Loose earth and stones..... 32 feet = 32 feet.
Red sandstone..... 29 " = 61 "

Supply, 10 gallons a minute at 18 feet from the surface.

BORED WELL AT PASSAIC FOR J. P. LANGE.

Sand and earth.....	42 feet = 42 feet.
Red sandstone.....	58 " = 100 "

Supply, 12 gallons per minute at 46 feet.

BORED WELL AT PASSAIC FOR PERCY W. SAUNDERS.

Earth.....	10 feet = 10 feet.
Red sandstone.....	54 " = 64 "

Supply, 4 gallons per minute.

BORED WELL AT GARFIELD FOR CLINE COLE.

Sand.....	52 feet = 52 feet.
Red sandstone.....	21 " = 73 "

Supply, 10 gallons a minute at 42 feet.

BORED WELL AT SOUTH ORANGE FOR WARREN C. BALL.

Commenced in bottom of old well, depth.....	30 feet = 30 feet.
Red shale rock.....	75 " = 105 "

Supply, 10 gallons a minute 30 feet from the surface.

BORED WELL AT LYONS FARMS, N. J., FOR F. W. C. CRANE.

Coarse red sand.....	67 feet = 67 feet.
Quicksand.....	40 " = 107 "
Coarse red sand again.....	8 " = 115 "

Supply, 5 gallons per minute.

BORED WELL AT BERNARDSVILLE, FOR MRS. E. L. JOLINE.

Loose stones and earth.....	29 feet = 29 feet.
Soft gray rock.....	93 " = 122 "

Supply, 5 gallons per minute.

BORED WELL AT HILLSBORO, FOR A. H. SONN.

Diameter, 6 inches. Depth, 116 feet.

Sand.....	33 feet = 33 feet.
Red shale.....	83 " = 116 "

Supply, 10 gallons per minute 21 feet from the surface.

BORED WELL AT PRINCETON, FOR FRANK GULICK.

Bastard red rock with streaks of shale 76 feet.

Supply, $2\frac{1}{2}$ gallons per minute.

BORED WELL AT PRINCETON, FOR MISS L. PARSHALL.

Earth.....	8 feet = 8 feet.
Hard blue rock, of the "nature of trap,".....	152 " = 160 "

Supply, 10 gallons per minute at 70 feet from the surface.

BORED WELL AT FLEMINGTON FOR DAVIS HANSON.

Earth.....	29 feet = 29 feet.
Shale	30 " = 59 "

Supply, $2\frac{1}{2}$ gallons a minute.

BORED WELL AT FLEMINGTON FOR L. B. HOFFMAN.

Earth.....	10 feet = 10 feet
Red shale.....	115 " = 125 "

Supply, 35 gallons a minute 29 feet from the surface.

BORED WELL AT SUNNYSIDE FOR JOHN S. CAVELIN.

Earth.....	8 feet = 8 feet
Red shale.....	42 " = 50 "

Supply, 10 gallons a minute 38 feet from the surface.

BORED WELL AT SUNNYSIDE FOR FARMERS' DAIRY DISPATCH.

Earth and loose rock.....	32 feet = 32 feet
Shale ..	71 " = 103 "

Supply, 8 gallons a minute 60 feet from the surface.

BORED WELL AT CLOVER HILL FOR THOMAS SEBRING.

Earth..... 20 feet = 20 feet
 Shale.....133 " = 153 "

Supply, 7 gallons per minute at 110 feet from surface.

BORED WELL AT WASHINGTON'S CROSSING FOR H. M. SWAYZE.

Red sandstone..... 33 feet = 33 feet
 Very fine-grained blue rock.....163 " = 198 "

Supply, 1 gallon per minute.

BORED WELL AT EWING.

Red shale from the surface to..... 71 feet.

Supply, 10 gallons per minute 20 feet from the surface.

BORED WELL AT TRENTON JUNCTION.

Earth..... 10 feet = 10 feet.
 Red shale..... 50 " = 60 "

Supply, 9 gallons per minute 20 feet from the surface.

BORED WELL IN BROOKLYN, N. Y., AT MALCOLM'S BREWERY, FOR
F. W. MILLER.

Sand and gravel..... 62 feet.

Water rose to within 8 feet of the surface of the cellar floor.

BORED WELL AT FAIRFIELD, CONN., FOR D. S. BEACH.

Earth..... 6 feet = 6 feet.
 Mica and gray rock, with flint seams..... 244 " = 250 "

Supply, 1 gallon a minute.

BORED WELL AT MAMARONECK, N. Y., FOR E. HAMILTON BELL.

Earth and top rock cased to..... 36 feet = 36 feet.
 Gneiss and mica rock, with hard, very hard and soft
 layers, each varying from 5 to 20 feet in thickness..... 155 " = 191 "

Supply, 10 gallons a minute at 125 feet.

BORED WELL AT EASTON, PA., ON COLLEGE HILL, FOR A. A. AICKER.

Cased.....	32 feet = 32 feet.
Soapstone.....	49 " = 81 "

Supply 35 gallons per minute at 68 feet from the surface.

BORED WELL AT YARDLEY, PA., FOR OWEN CLAYTON.

Earth.....	16 feet = 16 feet.
Red sandstone.....	39 " = 55 "

Supply 10 gallons per minute 40 feet from the surface.

BORED WELL AT TORRESDALE, PA., FOR POQUESSING ICE COMPANY.

Earth.....	31 feet = 31 feet.
Mica rock.....	12 " = 43 "

Supply, 30 gallons a minute 16 feet from the surface.

BORED WELL AT TORRESDALE, PA., FOR TORRESDALE LAND
IMPROVEMENT COMPANY.

Diameter, 8 inches; depth, 143 feet.

Earth and loose rock.....	48 feet = 48 feet.
Gneiss rock, with hard and soft streaks....	95 " = 143 "

Test, 35 gallons per minute at 75 feet from the surface.

BORED WELL AT ANDALUSIA, PA., FOR GEORGE G. PARR.

Diameter, 6 inches; depth, 60 feet.

Earth.....	20 feet = 20 feet.
Gneiss rock.....	40 " = 60 "

Supply, 15 gallons per minute 30 feet from the surface.

BORED WELL AT BRYN MAWR, PA., FOR MAURICE HECKSHER.

Earth.....	25 feet = 25 feet.
Micaceous rock.....	95 " = 120 "

Supply, 12 gallons per minute 60 feet from the surface.

BORED WELL AT BRYN MAWR, PA., FOR S. TWITCHELL.

Earth.....	23 feet =	23 feet.
Micaceous rock.....	48 " =	71 "
Black rock, very seamy, of "trap nature".....	65 " =	136 "

II.

Sec. 4.—Bored Wells Reported by P. H. & J. Conlan.

P. H. & J. Conlan, in response to our request, have furnished the records of a number of wells put down by them the past year. We also have had in hand the records furnished by them of wells sunk in 1891, which have been accidentally omitted from the annual reports of that and subsequent years. We first present their records for the present year and then append those for 1891. Collectively the wells are mostly in Essex and Hudson counties, and penetrate the Newark red shales and sandstones, though a few of them have encountered the trap dykes associated with that system of rocks. A few also of the wells are in Philadelphia, Pa., in Brooklyn and New York city, N. Y., and in Connecticut. The latter wells, excepting those in Brooklyn, penetrated micaceous gneiss rocks, some of them being of great depth.

The unusually deep wells—650, 1,007 and 2,200 feet in Jersey City, and 900 feet at Fort Lee—are worthy of special notice, since they furnish evidence of the great depth of the sandstone and trap rocks at the respective localities.

WELL IN JERSEY CITY FOR CONSOLIDATED TRACTION COMPANY.

In process of boring. Depth attained, 2,200 feet.

This well was noted last year as in process of boring and as having attained a depth of 1,400 feet entirely in red sandstone. P. H. & J. Conlan now write: "We are still working on the well for the North Jersey Traction Company at Jersey City. We are down 2,200 feet and the rock is very hard."

ARTESIAN WELL IN JERSEY CITY FOR HUDSON CANAL COMPANY.

Depth, 650 feet.

“ We also put down down a well for the Hudson Coal Company in Jersey City. This well is near the well of the traction company’s well and is down 650 feet, with very little water.”

WELL ON JERSEY CITY HEIGHTS FOR J. MEHL & CO.

Depth, 1,007 feet.

“ We have finished the well on Jersey City Heights for J. Mehl & Co. We got a good supply of water, over 150 gallons per minute. The water was analyzed and was of very good quality. It is 1,007 feet deep.” This well was reported last year (Annual Report, page 283) as in process of boring, having then reached the depth of only 275 feet, being entirely in trap below the depth of 20 feet. P. H. & J. Conlan now furnish the following complete record from the surface down, showing they probably got through the trap at the depth of about 365 feet :

Clay and boulders.....	20 feet =	20 feet.
Trap rock.....	344 “ =	364 “
A kind of white sandstone.....	336 “ =	700 “
Red shale with layers of white sandstone.....	307 “ =	1007 “

WELL AT COMMUNIPAW.

Depth, 500 feet.

“ We put down a well for G. V. Bartlett & Company’s slaughter-house ; at Communipaw ; the well was put down adjoining the bay ; we got salt water ; it is 500 feet deep.”

WELL AT BELLEVILLE NEAR NEWARK.

Depth, 150 feet.

“ We have put down a well for J. Frank Post in north Newark, near Belleville ; it is 150 feet in red shale ; it will produce over 150 gallons of water per minute.”

WELL AT WAVERLY.

Depth, 450 feet.

"We put down a well at Waverly, adjoining Newark, for the Weston Electric Instrument Company; it is 450 feet deep, with only a moderate supply of water.

WELL AT SUMMIT.

Depth, 325 feet.

"We put down a well for the Summit & Madison Ice Company, at Summit. It is 325 feet deep. The first 60 feet is through sand and gravel, then red shale; alongside of the well the trap-rock juts out about 100 feet distant. The well will produce about 100 gallons of water per minute."

WELL AT ARLINGTON.

Depth, 235 feet.

"We put down a well for the Standard Flint Paper Company, at Arlington, N. J. It is 235 feet deep. It is in shale and a good supply of water."

WELL AT ELIZABETH.

Depth, 275 feet.

"We put down a well for the Clause Bottling Company in Elizabeth; it is 275 feet in red shale, with a good supply of water."

WELL AT FORT LEE.

In process of drilling. Depth attained, over 900 feet.

"We are still drilling at the Convent well, at Fort Lee. We are over 900 feet, with no water, and are not through the trap-rock." This well was noted last year as in process of boring, having then reached 850 feet.

WELL IN NEW YORK, AT FIFTH AVE. AND FIFTY-FOURTH ST.

In gneiss rock. Depth, 240 feet.

"We put down a well in New York for the University Club, Fifty-fourth street and Fifth avenue. It is about 240 feet deep; it produces over 50 gallons of water per minute. We encountered gneiss and mica rock, and went through small strata of sulphate of iron and small veins of quartz. Where we started the well the rock was blasted away, they tell us, about 40 feet, so it was practically 300 feet from the original surface of rock to where we found water."

FIVE WELLS IN BROOKLYN, N. Y., IN THE 26TH WARD.

Average depth, 80 feet. One boring prospected to the depth of 140 feet.

Collective supply, 2,000,000 gallons per 24 hours.

"We have erected a pumping plant for the Long Island Water-Supply Company, 26th Ward, in Brooklyn, N. Y. We put down five wells, averaging in depth 80 feet. The supply, collectively, was 2,000,000 gallons per day of 24 hours."

The strata are:

Loam.....	4 feet = 4 feet.
Fine sand.....	6 " = 10 "
Gravel with water.....	25 " = 35 "
Thin vein of clay six to twelve inches, say.....	1 " = 36 "
Sand and gravel to, from 70 to 100 feet in depth, then clay.	

"We went to 140 feet with one well, but got no water; it was fine red sand with much iron, no gravel, and we went no deeper. The levels of the wells are about high-tide level, a very high-tide breaks up, so that they are all connected at tide level, but the water is fresh and good for use but a little hard."

WELLS IN CONNECTICUT ON LONG ISLAND SOUND.

Depth, 300 feet to 1,000 feet.

"We have put down several wells on Long Island Sound, on the Connecticut shore, from 200 feet to 1,000 feet, all the rock we met with in Connecticut was of gneiss character, the supply of water, moderate."

II.

Sec. 5. Bored Wells put down in the year 1891. Reported by
P. H. and J. Conlan.

The following wells were drilled in the year 1891, by P. H. and J. Conlan and were reported by them at that time but have been unintentionally omitted from the annual reports for that and subsequent years.

We quote P. H. and J. Conlan verbatim :

WELLS IN NEWARK, N. J.

"A. F. Bannister & Co.—Depth 120 feet ; 20 feet to rock, 100 feet in rock ; capacity 75,000 gallons water per day."

"C. N. Russell.—Depth 180 feet ; 10 feet to rock, 170 feet in rock ; capacity 36,000 gallons per day."

"Feigenspan Brewing Co.—12 inch pipe to rock ; 10 inch hole in rock. Depth 350 feet ; 100 feet to rock, 250 feet in rock ; capacity 288,000 gallons per day."

"Wheeler & Russell Hat Co.—Depth 250 feet ; formation, alternate layers of clay and quicksand, to water-bearing stratum ; capacity 108,000 gallons per day."

"McAndrews & Forbes Licorice Co.—Depth 220 feet ; 20 feet to rock, 200 feet in rock ; capacity 144,000 gallons per day."

WELL AT KEARNY, N. J.

"New Jersey Home for Disabled Soldiers.—Depth 600 feet ; 10 feet to rock, 590 feet in rock ; blue slate to a depth of 400 feet, and scarcely any water found till red sand-stone rock was encountered. Capacity 72,000 gallons per day."

WELL AT HARRISON, N. J.

"Hahn & Stumpf's Tannery.—Depth, 350 ft. ; 100 ft. to rock, 250 ft. in rock ; capacity, 72,000 gallons per day."

WELL AT WAVERLY, N. J.

"Ricketts & Banks.—Depth 280 ft. ; 80 ft. to rock, 200 ft. in rock ; capacity, 58,000 gallons per day."

WELL AT JERSEY CITY.

"Jos. Malone & Co.—Depth, 500 ft.; 40 ft. to rock, 460 ft. in rock; capacity, 72,000 gallons per day."

WELL AT SEWAREN, N. J.

"Port Reading R. R.—Depth, 250 ft.; 50 ft. to rock, 200 ft. in rock; capacity, 36,000 gallons per day."

WELLS IN PHILADELPHIA, PA.

"Arnholdt & Schaefer Brewing Co.—Drilled well from the depth of 900 ft. to that of 1,500 ft. At 900 ft. the well pumped about 9 gallons per minute; at present depth it pumps about 50 gallons per minute, but the temperature increased 5 degrees from 1,300 to 1,500 ft." This well is drilled entirely in the micaceous rocks of the Philadelphia belt of Southeastern Pennsylvania.

"George Keller Brewing Co.—Depth, 300 ft.; capacity, 22,000 gallons per day."

"Burg & Pfaender Brewing Co.—Depth, 150 feet; capacity, 51,000 gallons per day." The last two wells are in the same rocks as the well at Arnholdt & Schaefer's.

WELLS ON WESTERN LONG ISLAND.

"We have put down several wells, varying in depth from 25 ft. to 300 ft. Formation mostly clay and quicksand, with water bearing stratum generally found underneath clay beds."

PART IV.

Water-Supply from Wells.

BY

C. C. VERMEULE.

(145)

Water=Supply from Wells.

Studies were begun in 1890 to determine the volume of streams of the State and the available surface water-supply, and were continued in each annual report until 1894, when the results were summed up in Volume III of the Report on Water-Supply. It is now proposed to take up in like manner the well-water supply of the State, and while the subject is naturally more complex, and will not admit of such definite treatment as was found possible in the case of the surface supply, it is, nevertheless, believed that a careful analysis of the data now in hand and which may be obtained during the course of these studies, will elucidate certain problems connected with the development of underground waters and their utilization for public and domestic water-supply. There is undoubtedly much connected with the subject which cannot be reduced to a definite law. There are certain accidental features which sometimes upset all calculations, or are entirely at variance with reasonable expectation, but it must nevertheless be a help to those engaged in developing such supplies to know with more definiteness than at present what is a reasonable expectation of the yield of a well in a certain district. We believe it possible to throw some further light on this subject.

The importance of wells as a source of water-supply for the people of the State is steadily increasing. When the report on water-supply of 1894 was made it was shown, by a table on page 317, that about 6,500,000 gallons daily was obtained from wells alone, and 7,500,000 daily from combined wells and surface sources, out of a total of 108,000,000 gallons daily consumed by the cities of the State. The most notable wells at that time were those at Netherwood, supplying 1,603,000 gallons daily. Since then a group of wells has been put down northwest of Elizabeth, in the glacial drift on the watershed of Elizabeth river, which developed over 6,000,000 gallons of water daily. Another group of wells put down for the supply of the city of Camden are intended to furnish 20,000,000 gallons daily, and it is stated that they have actually yielded this amount on test. Smaller

plants have been installed at South Plainfield to supply Metuchen and Woodbridge, and at Chatham and Madison in Morris county. These and a number of other small plants have increased the well-supply of the State about fivefold since the canvass was made for the report of 1894.

There is a rather prevalent popular impression that underground water is entirely separate and distinct from surface water. Probably, to most minds, it appears that the water is taken from the earth in much the same manner that ore or coal is taken from a mine, entirely from the water held in store. A little figuring will show how impossible this is. Some of the recent important gang-wells put down for the city of Brooklyn, on Long Island, for instance, yield 20 million gallons daily. Such a yield during the period of one year amounts to a total of 7,300 million gallons. This amount of water would cover one square mile 35 feet deep, but in the average sandy soil the free water which can be extracted by wells does not amount to more than twenty-five per cent. of the total volume of the soil, or in other words, a continuous draft of 20 million gallons daily during one year would extract all of the water from one square mile of soil to a depth of 140 feet. If we remember that a public water supply means not a draft for one year, but a continuous draft for an indefinite period, it is clear that no wells can furnish such a supply unless there is constant replenishment. This replenishment must of course be from the original source of all water, the rainfall, and there is, therefore, no real distinction as to source between surface and underground supplies. The wells must be replenished continually from the surface. If they draw from a well-defined stratum of water-bearing sand or gravel, this replenishment is mainly from the outcrop of the stratum, although not entirely. In ordinary material, unstratified, or in which the strata are not separated by impervious beds of clay or other material, the well will be replenished by the rain falling upon the territory immediately adjacent to the well. The amount of water which will be available, upon such area, to replenish the well, is the difference between the rainfall and the evaporation, the latter including all water directly evaporated into the atmosphere, together with that taken into the tissues of plants and other vegetation. That is, supposing that the soil is sufficiently pervious to allow all of this water to percolate directly into the soil. This is not usually the case excepting in light, sandy or gravelly soils such as those of Southern

New Jersey or Long Island. In the more compact soils, such as those of our red sandstone and clay districts, a considerable percentage of the heavier rains will run off in the streams even though the soil may have been exhausted of its water by wells.

The amount of water available from one square mile, therefore, to replenish a well, cannot be greater than the amount available from one square mile to feed the surface streams. This amount was determined in the Report on Water-Supply for the several districts of the State, and is so necessary to this discussion that we repeat the tables here, with some modification. The table given below is Table No. 46 from the Report on Water-Supply, with a column added to show surplus or deficiency of rainfall over evaporation. The driest period covers parts of two years and is based on the famous drought of 1881 carried over into 1882, being the most severe of which we have any record from 1825 up to the present time :

Rainfall and Evaporation for Average Year and Driest Period, in Inches.

A surplus is indicated by +. A deficiency by —.

(a) UPPER DELAWARE VALLEY, HIGHLANDS AND KITTATINNY VALLEY.

MONTH.	AVERAGE.			DRIEST.		
	Rainfall.	Evaporation.	Surplus or Deficiency.	Rainfall.	Evaporation.	Surplus or Deficiency.
December.....	3.57	.60	+2.97	4.05	.74	+3.31
January.....	3.48	.55	+2.93	3.66	.57	+3.09
February.....	3.31	.55	+2.75	4.76	.69	+4.07
March.....	3.57	.74	+2.83	3.83	.76	+3.07
April.....	3.48	1.09	+2.39	.61	.83	— .22
May.....	3.88	2.35	+1.53	2.71	2.13	+ .58
June.....	3.88	3.07	+ .81	3.87	3.07	+ .80
July.....	4.05	3.73	+ .32	.96	2.91	—1.95
August.....	4.42	3.29	+1.13	1.18	2.58	—1.40
September.....	3.57	2.07	+1.50	.94	1.61	— .67
October.....	3.31	1.13	+2.18	3.04	1.10	+1.94
November.....	3.57	.90	+2.67	2.02	.76	+1.26
Year.....	44.09	20.08	+24.01	31.63	17.75	+13.88

December.....	.....	.....	.....	2.63	.60	+2.03
January.....	.....	.....	.....	4.57	.65	+3.92
February.....	.....	.....	.....	4.22	.64	+3.58
March.....	.....	.....	.....	3.57	.74	+2.83
April.....	.....	.....	.....	2.12	.96	+1.16
May.....	.....	.....	.....	5.06	2.55	+2.51
June.....	.....	.....	.....	1.90	2.64	— .74
July.....	.....	.....	.....	1.37	3.02	—1.65
August.....	.....	.....	.....	6.40	3.73	+2.67
September.....	.....	.....	.....	12.09	3.58	+8.51
October.....	.....	.....	.....	1.32	.92	+ .40
November.....	.....	.....	.....	.99	.67	+ .32
Year.....	.....	.....	.....	46.24	20.70	+25.54

Rainfall and Evaporation for Average Year and Driest Period
—Continued.

(b) CENTRAL DELAWARE VALLEY, RED SANDSTONE PLAIN, RARITAN WATER SHED.

MONTH.	AVERAGE.			DRIEST.		
	Rainfall.	Evaporation.	Surplus or Deficiency.	Rainfall.	Evaporation.	Surplus or Deficiency.
December.....	3.72	.83	+2.89	4.05	.87	+3.18
January.....	3.63	.66	+2.97	3.66	.67	+2.99
February.....	3.45	.67	+2.78	4.76	.82	+3.94
March.....	3.72	.89	+2.83	3.83	.90	+2.93
April.....	3.63	1.29	+2.34	.61	.98	— .37
May.....	4.04	2.81	+1.23	2.71	2.53	+ .18
June.....	4.04	3.70	+ .34	3.87	3.64	+ .23
July.....	4.23	4.43	— .25	.96	3.45	—2.49
August.....	4.59	3.96	+ .63	1.18	3.06	—1.88
September.....	3.72	2.49	+1.23	.94	1.91	— .97
October.....	4.45	1.36	+2.09	3.04	1.30	+1.74
November.....	3.72	1.03	+2.64	2.02	.90	+1.12
Year.....	45.94	24.22	+21.72	31.63	21.03	+10.60

December.....	.....	.....	.....	2.63	.71	+1.92
January.....	.....	.....	.....	4.57	.77	+3.80
February.....	.....	.....	.....	4.22	.76	+3.46
March.....	.....	.....	.....	3.57	.88	+2.69
April.....	.....	.....	.....	2.12	1.13	+ .99
May.....	.....	.....	.....	5.06	3.02	+2.04
June.....	.....	.....	.....	1.90	3.13	—1.23
July.....	.....	.....	.....	1.37	3.58	—2.21
August.....	.....	.....	.....	6.40	4.43	+1.97
September.....	.....	.....	.....	12.09	4.25	+7.84
October.....	.....	.....	.....	1.32	1.09	+ .23
November.....	.....	.....	.....	.99	.80	+ .19
Year.....	.....	.....	.....	46.24	24.55	+21.69

Rainfall and Evaporation for Average Year and Driest Period—Continued.

(c) DELAWARE WATER SHED, ABOVE TRENTON.

MONTH.	AVERAGE.			DRIEST.		
	Rainfall.	Evaporation.	Surplus or Deficiency.	Rainfall.	Evaporation.	Surplus or Deficiency.
December.	3.67	.70	+2.97	4.05	.73	+3.32
January....	3.57	.56	+3.01	3.66	.57	+3.09
February.....	3.40	.57	+2.83	4.76	.67	+4.09
March.....	3.67	.75	+2.92	3.83	.76	+3.07
April.....	3.57	1.09	+2.48	.61	.82	— .21
May.....	3.99	2.45	+1.54	2.71	2.13	+ .58
June.....	3.99	3.10	+ .89	3.87	3.17	+ .70
July.....	4.17	3.76	+ .41	.96	2.91	—1.95
August.....	4.52	3.32	+1.20	1.18	2.53	—1.40
September.	3.67	2.18	+1.49	.94	1.61	— .67
October.....	3.40	1.14	+2.26	3.04	1.10	+1.94
November.....	3.67	.92	+2.75	2.02	.76	+1.26
Year.....	45.29	20.54	+24.75	31.63	17.81	+13.82

December.....	.....	.....	.....	2.63	.60	+2.03
January.....	.....	.....	.....	4.57	.65	+3.92
February.....	.....	.....	.....	4.22	.64	+3.58
March.....	.....	.....	.....	3.57	.74	+2.83
April.....	.....	.....	.....	2.12	.96	+1.16
May.....	.....	.....	.....	5.06	2.55	+2.51
June.....	.....	.....	.....	1.90	2.64	— .74
July.....	.....	.....	.....	1.37	3.02	—1.65
August.....	.....	.....	.....	6.40	3.73	+2.67
September.....	.....	.....	.....	12.09	3.58	+8.51
October.....	.....	.....	.....	1.32	.92	.40
November.....	.....	.....	.....	.99	.67	.32
Year.....	.....	.....	.....	46.24	20.70	+25.54

Rainfall and Evaporation for Average Year and Driest Period— Continued.

(d) PASSAIC WATER-SHED.

MONTH.	AVERAGE.			DRIEST.		
	Rainfall.	Evaporation.	Surplus or Deficiency.	Rainfall.	Evaporation.	Surplus or Deficiency.
December	3.65	.78	+2.87	4.05	.83	+3.22
January	3.55	.63	+2.92	3.66	.64	+3.02
February	3.38	.64	+2.74	4.76	.78	+3.98
March	3.64	.84	+2.80	3.83	.86	+2.97
April	3.55	1.00	+2.55	.61	.93	— .32
May	3.96	2.67	+1.29	2.71	2.41	+ .30
June	3.96	3.49	+ .47	3.87	3.47	+ .40
July	4.14	4.24	— .10	.96	3.29	—2.33
August	4.50	3.74	+ .76	1.18	2.92	—1.74
September	3.64	2.36	+1.28	.94	1.82	— .88
October	3.38	1.29	+2.09	3.04	1.24	+1.80
November	3.65	1.02	+2.63	2.01	.86	+1.16
Year	45.00	22.70	+22.30	31.63	20.05	+11.58

December	2.63	.68	+1.95
January	4.57	.73	+3.84
February	4.22	.72	+3.50
March	3.57	.84	—2.73
April	2.12	1.08	+1.04
May	5.06	2.88	+2.18
June	1.90	2.98	—1.08
July	1.37	3.41	—2.04
August	6.40	4.22	+2.18
September	12.09	4.05	+8.04
October	1.32	1.04	+ .28
November .....	.99	.76	+ .23
Year	46.24	23.39	+22.85

Rainfall and Evaporation for Average Year and Driest Period—Continued.

(e) BRANCHES OF DELAWARE—TRENTON TO CAMDEN.

MONTH.	AVERAGE.			DRIEST.		
	Rainfall.	Evaporation.	Surplus or Deficiency.	Rainfall.	Evaporation.	Surplus or Deficiency.
December.....	3.82	.91	+2.91	4.05	.95	+3.10
January.....	3.73	.73	+3.00	3.66	.73	+2.93
February.....	3.55	.75	+2.80	4.76	.89	+3.87
March.....	3.82	.98	+2.84	3.83	.98	+2.85
April.....	3.73	1.41	+2.32	.61	1.06	— .45
May.....	4.16	3.08	+1.08	2.71	2.75	— .04
June.....	4.16	4.04	+ .12	3.87	3.95	— .08
July.....	4.35	4.91	— .56	.96	3.75	—2.79
August.....	4.71	4.33	+ .38	1.18	3.33	—2.15
September.....	3.82	2.73	+1.09	.94	2.07	—1.13
October.....	3.55	1.50	+2.05	3.04	1.41	+1.63
November.....	3.82	1.19	+2.63	2.02	.97	+1.05
Year.....	47.22	26.56	+20.66	31.63	22.85	+8.78

December.....	.....	.....	.....	2.63	.78	+1.85
January.....	.....	.....	.....	4.57	.83	+3.74
February.....	.....	.....	.....	4.22	.82	+3.40
March.....	.....	.....	.....	3.57	.36	+2.61
April.....	.....	.....	.....	2.12	1.23	+ .89
May.....	.....	.....	.....	5.06	3.28	+1.78
June.....	.....	.....	.....	1.90	3.40	—1.50
July.....	.....	.....	.....	1.37	3.89	—2.52
August.....	.....	.....	.....	6.40	4.81	+1.69
September.....	.....	.....	.....	12.09	4.62	+7.47
October.....	.....	.....	.....	1.32	1.19	+ .13
November.....	.....	.....	.....	.99	.87	+ .12
Year.....	.....	.....	.....	46.24	26.68	+19.56

Rainfall and Evaporation for Average Year and Driest Period— Continued.

(f) BRANCHES OF DELAWARE—CAMDEN TO BRIDGETON.

MONTH.	AVERAGE.			DRIEST.		
	Rainfall.	Evaporation.	Surplus or Deficiency.	Rainfall.	Evaporation.	Surplus or Deficiency.
December.....	3.72	.90	+2.82	4.05	.95	+3.10
January.....	3.62	.72	+2.90	3.66	.73	+2.93
February.....	3.44	.73	+2.71	4.76	.89	+3.87
March.....	3.72	.97	+2.75	3.83	.98	+2.85
April.....	3.62	1.40	+2.22	.61	1.06	— .45
May.....	4.04	3.05	+ .99	2.71	2.75	— .04
June.....	4.04	4.00	+ .04	3.87	3.96	— .09
July.....	4.22	4.86	— .64	.96	3.75	— 2.79
August.....	4.58	4.29	— .29	1.18	3.33	— 2.15
September.....	3.72	2.70	+1.02	.94	2.07	— 1.13
October.....	3.44	1.47	+1.97	3.04	1.41	+1.63
November.....	3.72	1.18	+2.54	2.02	.97	+1.05
Year.....	45.88	26.27	+19.61	31.63	22.85	+8.78

December.....	.....	.....	.....	2.63	.78	+1.85
January.....	.....	.....	.....	4.57	.83	+3.74
February.....	.....	.....	.....	4.22	.82	+3.40
March.....	.....	.....	.....	3.57	.96	+2.61
April.....	.....	.....	.....	2.12	1.23	+ .89
May.....	.....	.....	.....	5.06	3.28	+1.78
June.....	.....	.....	.....	1.90	3.40	— 1.50
July.....	.....	.....	.....	1.37	3.89	— 2.52
August.....	.....	.....	.....	6.40	4.81	+1.59
September.....	.....	.....	.....	12.09	4.62	+7.47
October.....	.....	.....	.....	1.32	1.19	+ .13
November.....	.....	.....	.....	.99	.87	+ .12
Year.....	.....	.....	.....	46.24	26.68	+19.56

Rainfall and Evaporation for Average Year and Driest Period— Continued.

(g) ATLANTIC COAST STREAMS OF SOUTHERN NEW JERSEY.

MONTH.	AVERAGE.			DRIEST.		
	Rainfall.	Evaporation.	Surplus or Deficiency.	Rainfall	Evaporation.	Surplus or Deficiency.
December	3.97	.97	+ 3.00	4.05	.95	+ 3.10
January	3.88	.75	+ 3.13	3.66	.73	+ 2.93
February	3.69	.76	+ 2.93	4.76	.89	+ 3.87
March	3.97	1.01	+ 2.96	3.83	.98	+ 2.85
April	3.88	1.44	+ 2.44	.61	1.06	— .45
May	4.32	3.11	+ 1.21	2.71	2.75	— .04
June	4.32	4.33	— .01	3.87	3.96	— .09
July	4.53	4.98	— .45	.96	3.75	— 2.79
August	4.91	4.39	+ .52	1.18	3.33	— 2.15
September	3.97	2.76	+ 1.21	.94	2.07	— 1.13
October	3.69	1.51	+ 2.18	3.04	1.41	+ 1.63
November	3.97	1.21	+ 2.76	2.02	.97	+ 1.05
Year	49.10	27.22	+21.88	31.63	22.85	+ 8.78

December	2.63	.78	+ 1.85
January	4.57	.83	+ 3.74
February	4.22	.82	+ 3.40
March	3.57	.96	+ 2.61
April	2.12	1.23	+ .89
May	5.06	3.28	+ 1.78
June	1.90	3.40	— 1.50
July	1.37	3.89	— 2.52
August	6.40	4.81	+ 1.59
September	12.09	4.62	+ 7.47
October	1.32	1.19	+ .13
November .....	.99	.87	+ .12
Year	46.24	26.68	+19.56

It will be noted in the above table that during the driest period there are many months in which evaporation exceeds the rainfall. This is true not only in such extreme drought, but during fully half of the years of any twenty-year period, and during such seasons there is not only no water available to replenish the well-supplies but even the

water in the ground will be further diminished by vegetation and evaporation. Such a dry period as we have given in the table furnishes the crucial test of the supplying capacity of a well, and we have shown that in planning public water-supplies depending upon stream-water they must be designed to insure a supply during such extreme periods. This is equally necessary in the case of well-supplies. Wells may supply a given quantity of water during several years, but may, nevertheless, fail when such a crucial test comes, and the failure is not less serious than in the case of surface-supplies. Indeed, it is usually much more embarrassing, because in the case of surface-supplies there is abundant warning given in advance; whereas in the case of wells the failure is sometimes very sudden and unexpected. The plate showing secular changes in annual rainfall which was printed in the Report on Water-supply, opposite page 13, will repay study in this connection, for it shows that the dry period sometimes extends over a series of years, and also that we may go through a period of fifteen or more of comparatively wet years, like that from 1858 to 1873, and then suddenly experience a very dry period, like that from 1877 to 1882.

The following summary from page 121 of the Report on Water Supply shows concisely how much water is available to feed a well or stream during the average year, the ordinary dry year, such as occurs about once in seven years, and the driest known year:

NET INCHES OF RAIN IN EXCESS OF EVAPORATION.

	Average Year.	Ordinary Dry Year.	Driest Year.
Upper Delaware Valley, Highlands and Kittatinny Valley	24.01	16.14	13.88
Central Delaware Valley, Red Sandstone Plain, Raritan Water-Shed	21.72	13.98	10.60
Delaware above Trenton	24.75	16.90	13.82
Passaic Water-Shed	22.30	14.39	11.58
Branches of Delaware—Trenton to Camden	20.66	12.65	8.78
“ “ —Camden to Bridgeton	19.61	12.01	8.78
Atlantic Coast Streams of Southern New Jersey,	21.88	13.98	8.78

The next table, which is taken from page 351, shows how much water we found flowing off in the streams during various periods for the different sections of the State. We have remarked that in some of the less permeable soils all of this water will not be available for wells, but the table will serve to show the maximum amount which is available.

RAINFALL AND AMOUNT OF RAIN FLOWING OFF.

Average Year.

	Rain—Inches.	Flow-off—Inches.
Kittatinny valley and Highland streams.....	44.09	24.41
Delaware above Trenton.....	45.29	24.75
Passaic water-shed.....	45	21.30
Red sandstone streams.....	45.94	21.72
Branches of Delaware, Trenton to Camden.....	47.22	20.66
“ “ Camden to Bridgeton.....	45.88	19.61
Coast streams.....	49.10	21.88

Driest Calendar Year.

Kittatinny valley and Highland streams.....	31.63	16.82
Delaware above Trenton.....	31.63	17.43
Passaic water-shed.....	31.63	15.53
Red sandstone streams, Hackensack.....	31.63	17.68
“ “ “ Raritan.....	31.63	16.25
“ “ “ small streams.....	31.63	14.83
Branches of Delaware, Trenton to Camden.....	31.63	17.62
“ “ Camden to Bridgeton.....	31.63	17.62
Coast streams with moderate ground-flow.....	31.63	17.62
“ “ “ large ground-flow.....	31.63	18.65

Driest Eighteen Consecutive Months.

Highlands and Kittatinny valley streams.....	51	21.06
Delaware above Trenton.....	51	21.24
Passaic water-shed.....	51	17.97
Red sandstone streams, Hackensack.....	51	18.26
“ “ “ Raritan.....	51	17.03
“ “ “ small streams.....	51	16
Branches of Delaware, Trenton to Camden.....	51	15.87
“ “ Camden to Bridgeton.....	51	15.87
Coast streams with moderate ground-flow.....	51	15.87
“ “ “ large ground-flow.....	51	17.14

We find that if we collect the surplus stream-waters of the wet months in storage reservoirs and deliver the water at a uniform rate, we can supply daily the amounts shown in the first column of the following table, but in order to do so there will be required, on each square mile of gathering ground, reservoirs of a capacity shown in the second column of the table.

GALLONS DAILY COLLECTIBLE WITH STORAGE FROM ONE SQUARE MILE.

		Storage needed per square mile. Gallons.
Kittatinny valley and Highland streams	666 094	121 642 752
Delaware river above Trenton.....	666 094	88 106 000
Passaic river.....	666 094	130 331 520
Red sandstone streams.....	570 938	110 200 000
Branches of Delaware, Trenton to Camden.....	570 938	86 018 803
“ “ Camden to Bridgeton.....	476 090	57,000,000
Coast streams.....	570 938	87,000,000

An equal amount can be supplied from wells for each square mile tributary to the well if all of the rainfall during our driest period percolates to the well, and if the amount of stored water within the influence of the well is equal to that shown by the table as the necessary storage. There are, of course, many cases in which the amount of stored water drawn upon by the well is largely in excess of the amounts given in the table. In such cases it may be assumed that the yield of an average year is available from each square mile of tributary gathering-ground. On this assumption the available supply is, practically, 1,000,000 gallons daily from each square mile for all sections of the State, and this may be taken as the maximum available supply from wells under the most favorable conditions.

The determination of the gathering-ground tributary to a well is a rather complex and difficult task, and it can rarely be accurately made except by an experienced engineer. The method of this determination depends entirely upon the class of well with which we are dealing, and this brings us to the question of a proper classification of wells. The several classifications which have been adopted do not always indicate differences important to the engineer. For the purposes of determining the gathering-ground and available storage, wells may be divided into two broad classes. First—We have the wells which draw water from a mass of more or less homogeneous material, like sand and gravel unstratified, or to some extent stratified, but which allows the water to percolate from the surface of the ground in all directions toward the bottom of the well. Second—We have a class of wells which draw their supply from pervious water-bearing strata which are overlaid by comparatively impervious strata.

In the first class are included most of the open dug wells, and also the comparatively shallow-tubed gang wells such as those at Freeport and Merrick supplying the city of Brooklyn, or those at Union and

Netherwood in this State. In the second class are included most of the deep-bored wells of Southern New Jersey, although comparatively shallow wells may be of this class also.

For this State the separation of wells which flow at the surface into a distinct class is not important. Indeed it is generally true in the Eastern United States that the use of the term "Artesian" as applied only to wells which flow at the surface, or the treating of such wells as a separate class leads to confusion. A well drawing from a given water-bearing stratum may flow at the surface if situated on low ground, while another on higher ground drawing from the same stratum will have to be pumped. Again, many of our wells, when first driven, flow at the surface, but cease to do so when a considerable quantity of water is pumped from them. It will be seen that the use of the term "Artesian" under such circumstances, as applied only to wells flowing at the surface has no practical significance. The papers by Mr. Woolman in the annual reports of this survey have used the term "Artesian" as applicable to all bored tube wells as distinguished from open dug wells. The phenomena of flowing wells are worthy of careful study, however, as they may serve to throw light upon the true source from which the well derives its water.

Wells may be divided into minor classes according to the methods by which they are sunk, but this is principally a matter of detail in the construction which may be taken up in that connection later on. So far as we have to do with the yield of a well, there is some minor importance to be attached to the classification into open wells and tubed wells, as we shall see later, but the two broad classes which we have given are practically the only ones of great importance in this connection.

For both classes of wells the yield is limited by the character of the material through which the water percolates to reach the well. We have some experimental data bearing upon the rapidity with which water will percolate through various materials under different heads, to which we shall refer later on.

CONDITIONS WHICH PRODUCE FLOWING WELLS.

Three of the conditions which produce flowing wells are illustrated in a paper on "Requisite and Qualifying Conditions of Artesian

Wells," by T. C. Chamberlin, contained in the fifth annual report of the United States Geological Survey. The first is shown in Fig. 11,

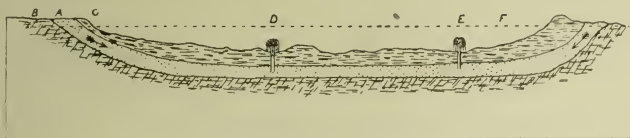


Fig. 11.

and consists of a pervious stratum overlaid and underlain by impervious material, both outcrops of which are elevated somewhat above the surface of the intervening country. Such a stratum becomes filled with water by the rainfall on the outcrops at A and G, so that wells sunk through the upper impervious clay at D or E will flow. It may be said that in most of these cases the material underlying the pervious stratum is of comparatively small significance, as it rarely happens that there is a free outlet downward for the water. The second condition is shown in Fig. 12, in which the bed has an elevated outcrop at

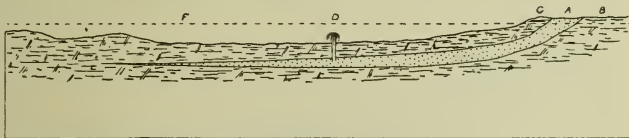


Fig. 12.

A, but thins out at its lower end, so that there is no outlet for the water, the beds above and below being of course impervious as before. The third condition is shown in Fig. 13. In this case the water-bearing

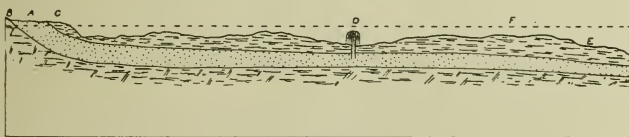


Fig. 13.

stratum has an elevated outcrop at A, but changes at its lower end E to an impervious material affording no free outlet for the water.

Besides these conditions given by Prof. Chamberlin, however, there are others which depend upon a different hydro-dynamic principle. The water bearing stratum may be of uniform character throughout, and may have a free outlet below for the water, and may,

nevertheless, produce flowing wells. This is owing to the fact that there is resistance to the flow through the stratum similar to the frictional resistance of a pipe or conduit carrying water. It is well known to hydraulic engineers that such a pipe as the one, 48 inches in diameter, which supplies Newark with the water from the Pequannock river, for instance, uses up a certain amount of head for every foot of its length in overcoming frictional resistance. Under ordinary conditions, for this particular pipe, this amounts to two feet for each thousand feet of length. Now, even when the pipe is discharging its normal amount of about thirty-five million gallons into the Newark reservoirs, some 284 feet lower than the intake, if a vertical standpipe should be connected with it at a point ten thousand feet down stream from the intake, the water would rise in this standpipe to within 20 feet of the level of the intake. If the standpipe is 20,000 feet down stream the water will rise within 40 feet of the level of the intake, &c. A line connecting the levels of water in a series of such standpipes would be known as the hydraulic grade-line of the pipe or conduit. A water-bearing stratum discharging freely at its lower edge may have a similar hydraulic grade-line. Thus, as shown in Figure 14,

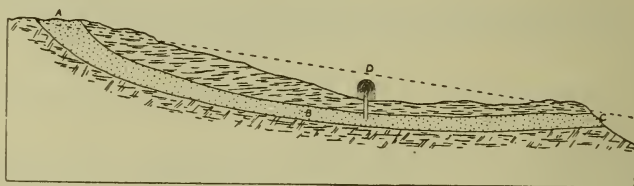


Fig. 14.

the pervious water-bearing stratum of sand or gravel, A, B, C, having an elevated outcrop at A, and a free discharge at C, will have a hydraulic grade line, A, D, C, and if a well-tube be sunk at any point D into the pervious stratum, the water will rise in the tube to this imaginary hydraulic grade-line.

A fifth condition, and one which produced most of the flowing wells along our sea-shore, depends upon the same hydraulic principle as the case given in Figure 14. If we trace the stratified beds of Southern New Jersey far out to sea, we shall have the general conditions shown in Figure 5, that is, taking the determined rate of slope of these beds and a profile of the sea-bottom made from the soundings of the United States Coast and Geodetic Survey, we find that, at a distance of about 100 miles off shore, the water-bearing strata have their lower

outcrop at the bottom of the ocean, as at C, and it is fair to presume that there is a free outlet for the water which they contain. They

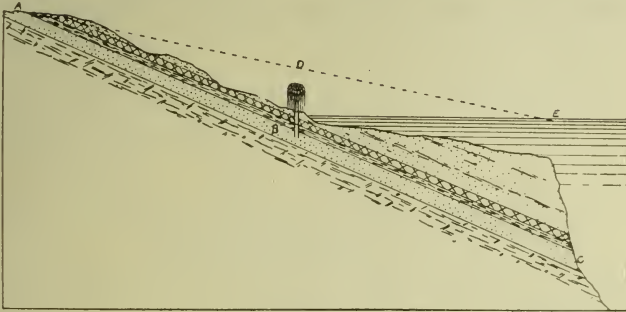


Fig. 15.

are discharging, however, against a head or pressure due to the sea water, so that the hydraulic grade at the outlet is the sea level. The hydraulic grade-line to which we have referred would, in this case, therefore, be a line joining the level of the elevated outcrop inland and a point at the ocean surface vertically over the lower outcrop of the stratum. Such a hydraulic grade-line will be considerably above the surface of the ground at points near the sea-shore. If a tube is put down into the water-bearing stratum at D, as shown in Figure 5, the water will rise in the tube to the hydraulic grade-line, and this probably explains the existence of flowing wells at several sea-shore points; thus, a well at Seven Islands rose 22 feet above the surface; one at Ocean City, 15 feet above; one at Great Sedge Island, 9 feet above; one at Mantoloking, 35 feet above; one at Ocean Beach, 50 feet above tide-level, etc. Incidentally, it may be pointed out that, in some of these wells, a tide has been observed corresponding in period but not in time with the tides of the ocean, and, as is to be expected, having a much smaller range than the ocean tide.

Although the cases shown in Figs. 11, 12 and 13 may exist somewhere in the Highlands or Kittatinny Valley region of the State, these cases have no important application to New Jersey wells. A special case of the conditions shown in Fig. 14, accounts for the existence of several flowing wells in northern New Jersey, the waters of which rise a few feet above the surface of the ground. Such a special case is shown in Fig. 16, both in plan and profile. In the flat bottom of a small valley, and extending somewhat on the slopes, there

is a local deposit of clay or alluvium rather impervious to water. This is underlaid by a pervious gravel, or it may be a seamy rock such as red shale. The rainfall collected in the upper portion of the valley passes down under the edges of this bed of clay, and then must

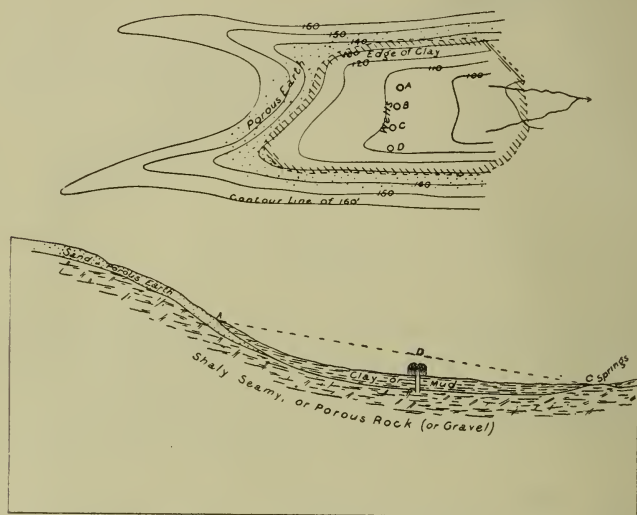


Fig. 16.

find its outlet underground, beneath the clay, to a point lower down the valley. If wells are sunk through the overlying clay in such a case, at A, B, or C, the water will rise a few feet above the surface of the clay. It does not follow that the overlying bed must be absolutely impervious. Some water may be constantly forced up through it and seep into the natural drainage channels, but this requires a slight head, which is represented by the few feet to which the water will rise above the surface when an opening is made through the clay-bed. In such cases, especially if the well happens to be sunk into the rock, the fact that it flows to some height above the surface is often accepted as conclusive proof that it has a distant source, but our illustration gives the true explanation, and shows that the gathering-ground of the wells may be only a few hundred feet distant. Finally it is conceivable that, in certain cases, wells may flow for a time from pressure exerted upon the water in the earth by compressed gases. A well put down at Sandy Hook struck gas at 150 feet deep, having a pressure estimated at 200 lbs. per square

inch, which "shot the sand and water in the air to a height of 75 to 100 feet, but gradually fell off, and in three days exhausted itself, after throwing out several hundred yards of sand and dirt with water." (See Annual Report for 1896, page 185.) Had such a well not penetrated the body of gas itself, but only a body of water against which the gas pressure was exerted in such a manner that the gas could not escape through the well, the result would have been a flowing well of more or less permanence.

CAPACITY OF THE EARTH TO ABSORB RAINFALL.

As to the rapidity with which the earth will absorb rainfall, some data were given in our investigation of the stream-waters of the State. Thus it was shown that the extremely heavy rainfall following September 20, 1882, amounted to 11.82 inches in 76 hours upon the Passaic and Raritan watersheds, culminating in a fall of about $6\frac{1}{2}$ inches in $16\frac{1}{2}$ hours. This heavy rainfall came after an extended drought, when the ground was very dry and 3.3 inches ran off in a freshet, on the Raritan, and about 3.13 inches in the Passaic. During a period of about 76 hours these watersheds absorbed, therefore, over $8\frac{1}{2}$ inches of rain, or at the average rate of about 2.4 inches in 24 hours. There was nothing to indicate that this was the limit, as the ground absorbed water until it was saturated, and the heavy floods which followed were due, not to a retarded absorption, but to saturation of the soil. At times during the early part of this storm rain fell on red sandstone country to the amount of 4 inches in 15 hours and was all absorbed. This is at the rate of over 6 inches in 24 hours. This rainfall was absorbed still more rapidly in the sandy soils of Southern New Jersey, the whole of this storm being absorbed there without causing freshets.

In our statistics of the flood of February, 1896, contained in the annual report of that year, it will be noted that the Passaic and Raritan watersheds absorbed about 1.6 inches of rain in 24 hours, this being the difference between the total rain and melted snow and the amount run off in floods. This percolation was quite uniform over the Highlands and red sandstone portions of these watersheds, and the ground was frozen and covered with snow and ice at the beginning of the warm rain which caused the floods. The percolation is much greater during the winter months than is generally supposed, although

it is true that if the ground is frozen very hard at a time when it is saturated with water, the percolation may be reduced materially.

Throughout Southern New Jersey and Long Island it may be accepted as true that the soil is capable of absorbing the rain as fast as it falls. The evidence of this will be seen in the general absence of severe floods and the lack of surface indications of wash, and in many instances the almost entire absence of any provision for surface-waters or floods. In the red sandstone country the surface sometimes becomes baked, and the soil naturally is not extremely pervious, so that a very heavy and sudden shower is not all absorbed even when the earth is quite dry. In the glaciated portion the capacity for absorption is much increased by the drift-gravels and sand. Measurements of the amount of rain flowing off in the streams in sudden freshets, however, lead me to conclude that even on the unglaciated red sandstone not more than ten per cent. of the total rainfall of any given month will fail to percolate into the soil if the soil is not already saturated with water. In general, my experience is to the effect that in any part of the State at least 90 per cent. of the quantities which I have previously given as available to replenish well-water supplies may be taken as a very conservative basis for estimates.

We may learn something of the capacity of mixed soils to pass percolating water from the amounts lost in this way from artificial channels. The Morris canal and the Delaware and Raritan canal both show a percolation loss of 8.5 inches depth of water in 24 hours. The Chesapeake and Ohio, Chenango and Erie canals show a loss of about five inches, while some of the irrigation canals of the West give results as high as 84 inches. A rate of from 18 to 20 inches of water in 24 hours is not unusual, either on the better constructed irrigation canals of the West or on the much older canals of Italy. Some very carefully constructed canals, such as the Languedoc in France, show less than 3 inches loss in 24 hours, but the figures previously given more nearly approach natural conditions. We may conclude from the indications afforded by the study of percolation statistics of a considerable number of canals that the water will percolate into such surface formations as those of Northern New Jersey at a rate of from 8 to 10 inches in 24 hours, and into sand and gravel at a rate of from 15 to 20 inches in 24 hours. In applying these figures taken from the canals it is assumed that the area into which the water percolates is the same as the area of water-surface of the

canal. I do not think that any substantial error results from this assumption, or that the figures thereby obtained are any too large. The percolation does not often extend over the entire bottom of the canal. If it is side hill construction it is quite usual to find some percolation into the canal on one side, which would offset the percolation loss which I have given and reduce the figures below the true amount. At best the figures are only rough approximations, but being obtained from considerable lengths of canal they give average results. It is, of course, true that there is a considerable amount of pressure available to increase the rate of percolation over that which would apply to a rainfall upon the surface. But taking all observed facts into consideration it may be stated broadly that if the ground-water is much exhausted by wells all of the water which we have given as available to feed streams will also be available for wells, unless it may be in unglaciated red sandstone or highlands country, where ten per cent. may be allowed for failure to percolate. We except clays, of course, as in these percolation is very slow.

Another fact which must be taken into account in considering the amount of water available to feed a well, is that if any streams, lakes or ponds come within the circle of influence of a well, or within the area from which rainfall would percolate to the well, the waters of these will usually be drawn into the well also. It is sometimes claimed that streams have a tendency to silt up their channels in such a way as to make them impervious to water, but I have not usually found this to be true, even with our muddy red sandstone streams. If any of these streams are dammed and diverted, so that no water passes the dam, it will be found that, below the dam, the water soon gathers up into a stream of some volume, showing that there are many springs, or there is much seepage water coming into the bed of the stream.

Again, I have gauged streams at points some miles apart and found much greater gain in volume than could be accounted for by the intervening tributaries, also showing the incoming of seepage water. This is always to be expected, as the stream channel is the natural outlet for ground-water along its course. Of course, where water is continually coming into a stream through the sides and bottom of its channel, there can be no such thing as a formation of a water-tight lining of silt, and, if the opportunity is offered, the water will go out where it come in. Instances may occur where, for a limited distance,

a stream passes over a clay bed which is practically water-tight, but these are to be regarded as exceptional cases. The Morris canal is now 65 years old, and percolation still goes on, as we have noted. The same is true of the Delaware and Raritan canal, and of Italian canals more than one hundred years old, so that it is at least a reasonable expectation that, if a well has extracted the ground-water from beneath the bed of a stream, the waters of the stream will follow this ground-water into the well.

RATE OF INFLOW THROUGH NATURAL MATERIAL SURROUNDING THE WELL.

We can best study the problem of the range of influence of a well and the conditions which govern the rate of inflow, by assuming it to be sunk in a homogeneous material such as sand or gravel. In the case of a tube well all of the water must reach the well through a strainer at the bottom, and various methods are employed for removing the finer material from about the strainer so as to leave a considerable bed of rather coarse gravel immediately surrounding the strainer. But there is no practical way in which this can be done at any considerable distance from the strainer. In most cases it is safe to assume that all the water reaching the well will have to pass through the natural material surrounding the strainer at a distance of about five feet from its centre. On this assumption, which of course needs modification for some cases, the problem of determining the rapidity with which the water will reach the well reduces to a question of how fast it will pass through a square foot of this naturally compacted material, and having determined how much will thus pass, we may multiply by the number of square feet in the surface of a sphere of five feet radius to determine the volume of inflow to the well. If the strainer is a long one, materially exceeding ten feet in length, this area might be increased to that of a cylinder ten feet in diameter and of the same length as the strainer. In the case of an open well the water must pass upwards into the well at the bottom, and in this case the finer particles will sometimes wash out, or may be excavated in such a way that the inlet for the water, through the natural material, may be assumed to be equal to the surface of a hemisphere having a diameter equal to the diameter of the well. Supposing a well to be pumped at a continuous rate, therefore the

surface of the ground-water near the well will soon assume a slope which corresponds with the rate of discharge into the well. If we conceive the centre of the strainer to be circumscribed by a number of spheres in the manner indicated in Figure 17, the water will have to

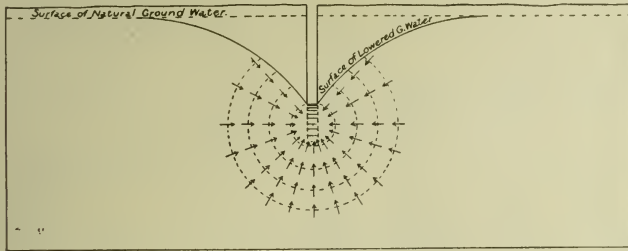


Fig. 17.

pass through the area represented by surfaces of these several spheres as it proceeds on its way to the well. Now, these surfaces vary as the square of the radius of the spheres, consequently the velocity of flow of the water toward the well will vary inversely as the square of the distance from the well. Experiments made by Darcy and elaborated by Dupuit showed that for sands the velocity varies directly as the head. This law does not hold true for very coarse and clean gravels, but may be accepted as usually true for our present purposes, consequently it will be seen that the slope assumed by the ground-water will vary inversely as the square of the distance from the well. The result will be that the water will be extracted from the ground immediately surrounding the well in the way indicated by Figure 17, which shows the limits of what is usually called the well-cone, although it is not a true cone, but has a cross-section similar to that shown in the figure. The extent of this cone, and consequently the distance to which the water can be extracted by the operation of the well, will be determined by the resistance offered by the material immediately surrounding the bottom of the well, and by the depth of the well. The quantity of water which a single isolated well will permanently yield under such typical conditions as we have here assumed, will be usually determined almost solely by the resistance of the undisturbed natural material nearest to the strainer to the passage of the inflowing water.

In the case of a well sunk to a confined water-bearing stratum the conditions of inflow are slightly different, as shown in Figure 18. In this case the inflow through the pervious stratum to the bottom of the well may be considered to pass a series of cylinders, instead of spheres,

for all cases where the thickness of the stratum does not exceed 15 or 20 feet. For thicker strata, the ground-water will, in some cases, assume a slope as in Figure 17, but only when the well is pumped

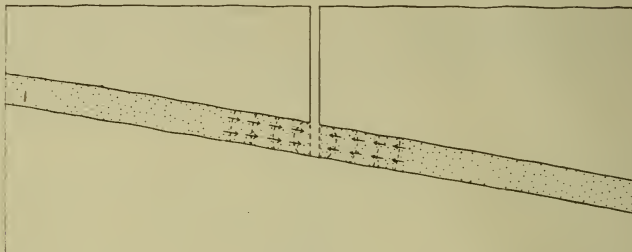


Fig. 18.

down to the water-bearing stratum. For such a case as this the rate of inflow to the well has a fixed limit, the determining factors of which are the nature of the material and the slope of the water-bearing stratum from its source toward the well. Inasmuch as the water is rarely pumped down in such a well anywhere near to the water-bearing stratum this limit is very rarely reached, for the inclination which forces the water through the sand toward the well must be determined by the difference between the height of water in the well and the height of permanent ground-water at the outcrop of the stratum, divided by the distance to the well from the outcrop. In no case, however, can this inclination be greater than the inclination of the water-bearing stratum, as we have noted.

The law being as we have stated it, that the velocity of inflow varies directly as the head or inclination for a given material, the yield of such a well will be increased in direct proportion to the distance to which the finer material of the stratum can be removed from the well-strainer.

In order to determine the possible rate of inflow to a well it becomes necessary to have some data as to the rapidity of flow of water through various materials for given heads or slopes. The following table is taken from Bulletin No. 33, of the Colorado Experiment Station, being a paper on "Seepage, or Return Waters from Irrigation," by L. G. Carpenter :

TABLE FOR VELOCITY OF FLOW THROUGH PERMEABLE SOILS.

Values of k in formula $v = ki$. $V =$ velocity in feet, $i =$ inclination or fall in feet per foot.

KIND OF MATERIAL.	Size of Grains, Inches.	Voids, Proportion of.	VELOCITY IN FEET.			
			Per Second.	Per Hour.	Per Day.	Per Year.
Minute Gravel.....	.08	0.41	.024	86.47	2075.	757520
Coarse Sand		0.38	.0026	9.33	224.	81730
Fine Sand.....	.008	0.35	.00047	1.69	40.5	14777
Sandy Soil.....		0.30	.00032	.79	18.9	6897
Sandy Clay.....		0.25	.00012	.42	10.2	3725
Clay.....	{	0.20	.00003	.12	2.8	1035
			.00008	.295	7.1	2587

To use this table in practice it is only necessary to multiply the above figures for velocity by the slope of the surface of the ground-water in the soil, since for such soils the velocity varies directly as the slope. The table gives the velocity for a slope of one to one, or forty-five degrees.

The next table has been compiled from one which is published in the report of the Massachusetts State Board of Health for 1892, page 554. This table is made up from the results from a number of experiments made in connection with the study of filter-sands by Mr. Allan Hazen. I have reduced the figures, which are given in meters and millimeters, to feet and inches.

TABLE SHOWING RATE AT WHICH WATER WILL PASS THROUGH DIFFERENT SANDS, WITH VARIOUS HEADS, AT A TEMPERATURE OF 50 DEGREES FAHRENHEIT.

Feet Per Day.	i	Effective size of Sand in Inches, 10 per cent. of grains finer than—									
		004	008	.012	016	.020	039	.118			
	001	0 03	0 13	.29	.52	.82	3 28	29 5	.....	.....	.....
	.005	0 16	0 66	1 47	2 62	4 10	16 4	147.	.....	.....	.....
	.010	0 33	1 31	2 95	5 24	8 20	32 8	295.	.....	.....	.....
	.050	1 64	6 56	14 7	26 2	41	164	.....	.....	.....	.....
	.100	3 28	13 12	29 5	52 4	82.	328	.....	.....	.....	.....
	.500	16 4	65 6	147.	262.	410	.....	.....	.....	.....	.....
	1 000	32 8	131.	295.	524	.....	.....	.....	.....	.....	.....
	2 000	65 6	262.	180	1048	.....	.....	.....	.....	.....	.....

	<i>i</i>	Effective size of Gravel in Inches, 10 per cent. of grains finer than—										
		.118	.164	.262	.328	.492	.656	.820	.984	1.15	1.31	
Feet Per Day.	.0005	12	33	66	98	164	262	361	492	656	820	.....
	.001	23	69	134	190	328	485	672	903	1260	1475	.....
	.002	46	131	256	361	624	903	1210	1570	1930	2330	.....
	.006	134	367	680	900	1470	2030	2550	3050	3570	4070	.....
	.010	220	570	980	1260	2000	2730	3360	4000	4630	.....	.....
	.050	920	1830	2900	3470	4900	.....	.....	.....	.....	.....	.....
	.100	1620	3050	4300	5100	.....	.....	.....	.....	.....	.....	.....

The above figures show the number of cubic feet of water which will pass through one square foot of sand with the given slope, not the actual rate of travel of a particle of water through the sand, which will be faster in the ratio of the total volume of the sand to the volume of the voids occupied by the water, or about two and one-half times the velocity shown in the table.

The following table, showing the effect of variation in temperature upon the amount of water flowing through the soil, is given in the same report, and I here insert it, as it may possibly be useful in this connection, although the above velocities being given for fifty degrees Fahrenheit, may often be used without correction.

RELATIVE QUANTITIES OF WATER PASSING AT DIFFERENT TEMPERATURE.

Degrees, Centigrade.....	0	5	10	15	20	25	30
Degrees, Fahrenheit.....	32	41	50	59	68	77	86
Quantity.....	.70	.85	1 00	1 15	1 30	1 45	1 60

Mr. Hazen says that the data for gravels are less complete than could be desired. The tables are made up by plotting the actual

experiments and making a diagram from which the above figures were taken. It is also noted in the above report that for coarse gravels the velocity varies as the square root of the head instead of directly with the head, as is the case with sands. It may be remarked in this connection that it has been noted that for many of the artesian wells of Queensland, Australia, which flow under widely varying pressure, the discharge is proportional to the square root of the head or pressure, but that at some wells the flow appears to be more nearly in direct proportion to the head. (See Fourteenth Annual Report of the Hydraulic Engineer on Water-Supply, 1898, page 11.)

SEEPAGE FROM SOME CANALS. CUBIC FEET OF WATER PER SQUARE FOOT.

Canals.	Seepage per day in feet.	Remarks.
Fort Morgan, Col.....	0.98	Sandy soil.
Fort Morgan, Col.....	5.00	New canal, (i equals about .01.)
Hoover Ditch, Col.....	1.2	Sandy soil.
Kings River and Fresno.....	1.5	Sandy soil.
Kings River and Fresno.....	1.7	Sandy soil.
Kings River and Fresno.....	0.6	Sandy soil.
Fresno.....	0.4 to 2.8	Different sections.
Fresno Laterals.....	1.2 to 6.4	
Naviglio Grande, Italy.....	0.9	} Italian canals 100 years old in very pervious soil.
Muzza, Italy.....	1.7	
Canale Martesana, Italy.....	1.5	
Languedoc, France.....	0.23	Carefully constructed.
Chesapeake.....	0.42	} American canals in rather im- pervious soil.
Chenango.....	0.42	
Erie.....	0.42	
Morris.....	0.71	
Delaware and Raritan.....	0.71	

The ordinary rate shown above is from 0.4 to 1.5 feet for ordinary to rather pervious soils, ranging upward to 5 or 6 feet in extremely pervious soils. These figures (0.4 to 1.5) correspond approximately with Hazen's for inclination .01 and materials classed as ten per cent. finer than .004 to .008 inches, and it seems probable that such would be about the average condition under which seepage occurs.

The figures above given for canals are not applicable to the problem of inflow to a well at points near the strainer, because if a well is pumped at anywhere near its maximum yield, the value of i , or the inclination of the surface of the ground-water, will be much greater than it is under such conditions as we have in the case of canal seep-

age, but these figures may be suggestive of conditions at points more remote from the well strainer.

When a well is yielding at its maximum rate, the slope of ground-water in the undisturbed natural material nearest the strainer must be one to one. This is under the assumption, of course, that the resistance of this material to inflow is the controlling factor in the yield of the well. It would not be true in extremely coarse gravel. The slope cannot exceed one to one unless the well is sunk in or near to a pond or other body of water standing on the surface. The figures given in Mr. Hazen's table for slopes exceeding one to one refer to free standing water on the surface of the sand or other material, such as would occur on a filter-bed. In considering sands and gravels in their natural position it should be remembered that ordinarily they contain a considerable amount of fine material, and Mr. Hazen has pointed out the controlling influence of the ten per cent. of finer material in the mass for determining the rate of flow.

The figures given in the following table for infiltration galleries are determined under conditions which make them fairly reliable, and they appear to be directly applicable to the rate of inflow to a well through such porous material as these galleries are constructed in :

OTHER RATES OF INFLOW.

	Gallons per day per sq. ft.	Feet per day.
Infiltration galleries, at Lowell, Mass. Test showed that the inflow through sand and gravel was.....	150	20
Infiltration gallery, at Brookline, Mass. Material clean, coarse sand and gravel.....	245	33
Toronto basin.....	52	7
Gallery at Perth, Scotland.....	182	24
“ “ Angers, France.....	187	25
“ “ “ “ (new)	300	40
“ “ Lyons, “	147	20
“ “ Toulouse, “	228	30
Open well at Rio Grande, Cape May county, N. J.....	1,070	143
“ “ at Long Island City (W. J. Matheson & Co.), in fine micaceous sand mixed with gravel (i equals 0.6).....	360	48
Inflow to this well varied directly as the head.		
Open well at Prospect Park, Brooklyn, (i equals 0.45), material sand and gravel.....	884	118

The above figures would seem to indicate that ordinary sands mixed with gravel, as they occur under natural conditions, offer as much re-

sistance to flow as Mr. Hazen's sands "10 per cent. finer than .012 inches."

Now, if we assume that a well draws its water through the natural material at a distance of about five feet from the center of the strainer, the circumscribed sphere of five feet radius has an area of 314 square feet. A velocity of inflow of one cubic foot of water per square foot per day will give a yield of 314 cubic feet, or 2,350 gallons per day, or 1.63 gallons per minute. It will be noted that a number of infiltration galleries in sand and gravel give a rate of inflow of from 20 to 30 feet per day. Applying this rate to the assumed well we will have an inflow of from 47,000 to 70,000 gallons daily. These are rates which actually obtain in a very considerable number of wells on Long Island and in New Jersey, where the wells draw from a mass of practically unstratified sand and gravel. That is, a large number of wells have proven by actual test that the rate of inflow is as great as this. The question as to whether that rate can be maintained permanently depends upon other considerations. Now, as the water approaches the strainer from a distance of five feet it passes through a constantly decreasing area and must consequently have a constantly increasing velocity. In order to admit of such an increase of velocity the finer particles about the strainer must in some way be removed. This will often be effected by the scour of the inflowing water, and will be washed into the well, but there are various methods adopted by practical well constructors for effecting its removal, experience having shown this to be necessary. If we assume a strainer ten feet long, a cylinder circumscribed about it with a radius of six inches from the center of the strainer will present an area of 31.4 square feet, or 1-10 of that of the above circumscribed sphere, consequently all the water will have to pass this area at a rate ten times faster than the rate at which it passes the assumed sphere, or in the above-mentioned case at a velocity of from 200 to 300 feet per day. Comparing Mr. Hazen's table it will be seen that the velocity of 20 to 30 feet per day at the surface of the assumed sphere, when the value of i equals 1, applies to a material finer than the finest given in Mr. Hazen's table, and somewhere between the sandy soil and the fine sand of Prof. Carpenter's table, while the higher velocity near the strainer, of from 200 to 300 feet per day, would require for the same slope a material as coarse as the third on Mr. Hazen's list, that is, the finer

10 per cent. must be raised from .004 inches to .012 inches, but in reality it should be considerably coarser than this, because the slope of the water should not be required to be greater than one in ten, which would require the material to be raised to 10 per cent. finer than .039 inches. There should be no difficulty in effecting such an improvement in the coarseness of the material as would produce such a result.

The following table, based on the Carpenter and Hazen tables previously given, may be found convenient as showing at a glance the possible rate of inflow to a well through the various grades of material given in those tables; the value of i being 1, excepting for the coarse gravels for which it is 0.1.

Rates of inflow to a well through material of a given fineness, at the surface of an assumed sphere having five feet radius from the center of the strainer, based on the foregoing tables.

DESCRIPTION OF MATERIAL.	Size of Grains, inches.	Inclination of Ground-Water.	POSSIBLE RATE OF INFLCW.		
			Cubic feet per day.	Gallons per day.	Gallons per minute.
Carpenter's Table.					
Minute Gravel.....	.08	1.0	651,550	4,860,000	3,380
Coarse Sand.....		1.0	70,336	520,000	360
Fine Sand.....	.008	1.0	12,717	95,000	66
Sandy Soil.....		1.0	5,935	44,000	30
Sandy Clay.....		1.0	3,203	23,900	17
Clay.....	{	1.0	879	6,500	4.5
			to	to	to
		2,229	16,500	11.5	
Hazen's Table.			Sands.		
Ten per cent. finer than.....	.016	1.0	164,536	1,230,000	850
Ten per cent. finer than.....	.012	1.0	92,630	695,000	480
Ten per cent. finer than.....	.008	1.0	41,134	307,000	210
Ten per cent. finer than. ....	.004	1.0	10,299	75,000	52
			Gravels, smaller incli	nation.	
Ten per cent. finer than. ....	.328	0.1	1,601,400	11,975,000	8,300
Ten per cent. finer than.....	.262	0.1	1,350,200	10,100,000	7,000
Ten per cent. finer than.....	.164	0.1	957,700	7,175,000	5,000
Ten per cent. finer than.....	.118	0.1	508,680	380,000	2,650
Ten per cent. finer than.....	.039	0.1	102,992	750,000	520
Ten per cent. finer than.....	.020	0.1	25,748	192,000	134

The above table illustrates clearly the importance of the character of the material in determining the possible yield of the well.

A further study of this question of possible inflow will be made in the course of this investigation by collecting records of maximum yield of wells in given classes of material. Tests of maximum yield of a well made shortly after the well is sunk are of value in this connection, although they may be absolutely valueless in determining the amount of water which the well will continue to yield for a long period of time, because this may be limited by other conditions than the resistance offered by the material to the inflow of water. We append some notes of such maximum yields of wells, which are to be extended by further collections of data.

MAXIMUM YIELD OF SOME TUBED WELLS. TO ILLUSTRATE POSSIBLE RATE OF INFLOW.

WELLS IN SAND AND GRAVEL.				REMARKS.
Diameter of Tube, in inches.	Depth of Well, in feet.	Yield in Gallons per day.	Rate of Inflow, in feet.	
2	40 to 60	50,000	21	Average of 124 wells in a "gang," Brooklyn water-works.
2	.....	70,000	30	Average of 100 wells, Brooklyn water-works.
2	29	36,000	15	In fine micaceous sand, Long Island City.
2	40	65,000	28	In gravel at Belleville, average of 10 wells.
3	65 to 102	144,000	60	Average of 6 wells at Gloucester.
2 and 3	80 to 105	216,000	90	Average of 6 wells at Clayton.
3	50	144,000	60	Freehold, in coarse sand.
3	485	36,000	15	Ocean Beach.
3	480	70,000	30	Ocean Beach.
3	48	175,000	75	Pleasant Mills.
3 and 4	600 to 1,100	200,000	84	Average of 7 wells at Asbury Park, in sand.
4	205	29,000	12	In sand, Vineland.
4½	128 to 141	288,000	120	Average of 4 wells at Merchantville.
4½	67 to 162	100,000	42	Average of 9 wells at Gloucester, in gravel strata.
6	200	288,000	120	At Newark, in gravel.
6	225	108,000	42	At Newark, in sand.
6	40	72,000	31	At Newark, in quicksand.
4 to 6	450 to 1,200	100,000	42	Ocean Grove, average of 21 wells in sand.
6	46	648,000	276	Cinnaminson, in 4 feet of gravel overlaid by 10 feet of sand.
8	65 to 95	400,000	168	Average of 6 wells at East New York.
.....	1,130	250,000	105	Asbury Park, in coarse sand.
8	575	180,000	77	Beach Haven, in sharp gray sand.
8	960	300,000	128	Atlantic City, in sand.

The above rate of inflow is computed for an assumed sphere circumscribed about the center of the well-strainer, or perforated part of the tube. For the larger wells the strainer is often 20 feet long or more. If 20 feet long, and the natural sand or gravel is undisturbed at an average distance of 27 inches from the center of the well, the above rate of inflow will be correct. If the finer particles are removed to a distance of 5 feet from the center, however, then the rate of inflow through the natural material would be only half of that given in the above table. I have purposely omitted wells flowing under heavy pressure, as these must be studied by themselves, and are practically unknown in this State.

DETERMINATION OF THE GATHERING-GROUND.

The law which determines the limits of the well-cone for a single isolated well which is drawing a supply from a homogeneous material, neglecting for the present the replenishment to the cone caused by the rainfall, has been already alluded to. I will now state it more fully. When a well is producing its maximum yield the slope in the undisturbed natural material nearest to the well will be one to one. This is supposing, of course, that the resistance of the material is the limiting condition of the yield. This slope will decrease in proportion to the square of the distance from the well. If the slope at a distance of five feet, for instance, is one to one, at 50 feet it will be one to one hundred, and at 500 feet one to ten thousand. Since under this law the slope can never become zero, theoretically the influence of such a well will extend to an infinite distance, supposing it to be sunk deep enough below the natural level of ground-water. This depth under the above conditions need not exceed 12 feet, measuring from the level of permanent ground-water to the top of the strainer. Figure 19 is a diagram, showing the limits to which the

Fig. 19.

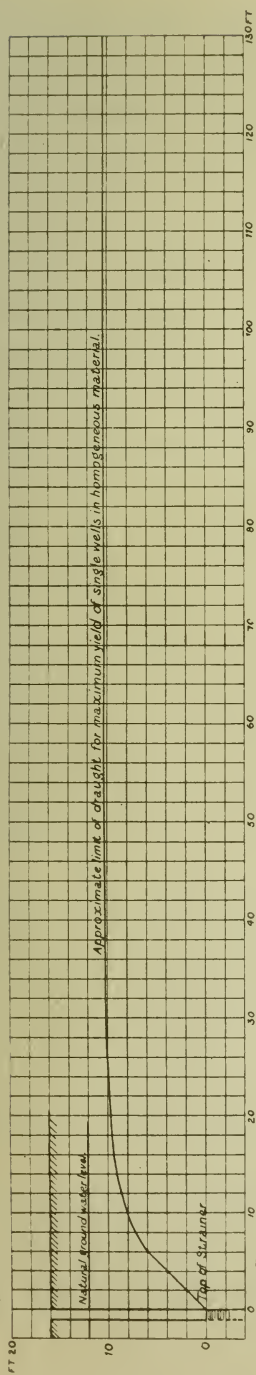
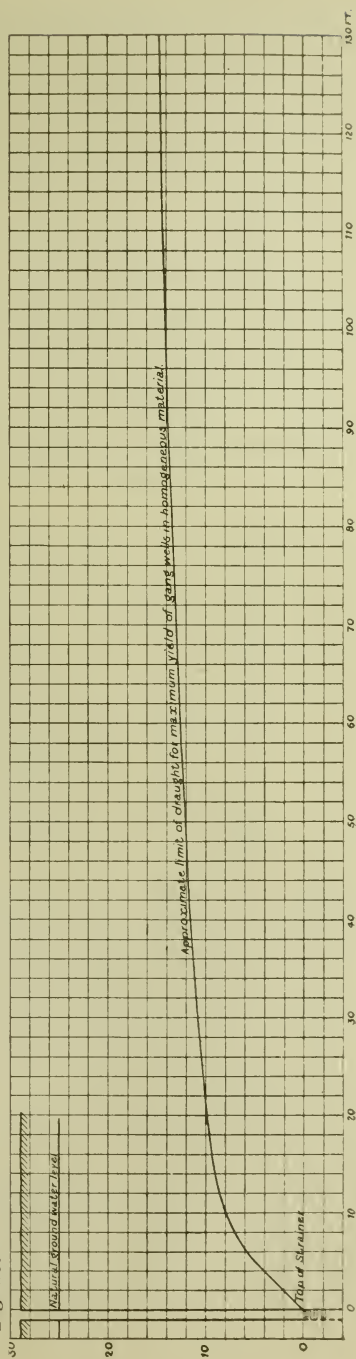


Fig. 20.



ground-water can be drawn by such a well. Strictly speaking, there should be an allowance made for the fact that the well-cone itself cuts off a constantly increasing segment of the circumscribed spheres which represent the areas through which the inflow must reach the well. Near the outer limits of the well-cone this segment approximates to half of the sphere, but for all practical purposes the law may stand as we have stated it.

While the tendency of the well in dry weather will be to draw down the ground-water more or less closely to this theoretical limit, it will never quite reach this, because we must consider the effect of the constant replenishment of the supply from the rainfall upon the well-cone. If we take this to be, for an average year, one million gallons daily per square mile, and for the driest period two-thirds as much, as previously stated, the following table shows the draft which may be kept up continuously from a circle of given radius about the well :

Radius of Circle About Well.		Gallons Daily Which May be Drawn Therefrom. Average Year.	Gallons Daily Which May be Drawn in Driest Period.
In miles.	In feet.		
.1	528	31,416	20,944
.2	1,056	125,664	83,776
.3	1,584	282,743	188,495
.4	2,112	502,665	335,110
.5	2,640	785,398	523,599
.6	3,168	1,130,970	753,980
.7	3,696	1,539,380	1,026,253
.8	4,224	2,010,620	1,340,413
.9	4,752	2,544,690	1,696,460
1.0	5,280	3,141,590	2,094,393

This shows that a well which furnishes 125,000 gallons daily cannot permanently extend its cone beyond one thousand feet from the well, as at this distance the draft will be constantly replenished. Of course, during a dry period the cone may extend two or three hundred feet further, but later on the rainfall will reduce it to its normal radius. The best producing well in the list previously given will not permanently extend its draft cone half a mile from the well, and those wells which produce under 70 thousand gallons per day will only be felt at 800 feet distance.

For a long line of gang wells, connected and all pumped together, a different law will obtain. For such a case we may conceive that the water must flow to the wells through a cylinder of five feet radius, circumscribed about the line adjoining the centres of the strainers, and

as the water approaches the well from a distance it will successively pass through a series of cylinders, instead of the spheres of a single well. The area of the cylinder will vary directly as the distance from the well, consequently the velocity of the inflowing water and the slope of the ground-water on a line at right angles to the line of wells will vary inversely as the distance, instead of the square of the distance. Thus, if at five feet it is one to one, at 5,000 feet it would be one to 10,000. If the wells are twenty feet apart, then for at least ten feet from the well the law will be the same as for a single well, and if the inclination at five feet distance is one to one, at ten feet it will be one to four, and beyond that it will vary inversely as the distance, and will be one in 40 at 100 feet, one in 400 at 1,000 feet, and one in 2,000 at 5,000 feet. This approximates to what the writer has actually observed in the case of such wells, and the limit of draft illustrated in Figure 20 as applicable to gang-wells is determined in accordance with such a condition.

At Merrick, Long Island, careful observation of a line of gang-wells half a mile long, in sand and gravel, gives the following results. Pumping began January 23d at a rate of six million gallons daily and gradually fell off until, during the months of February, March and April following, the average rate was 5,000,000 gallons daily, and thereafter it gradually fell off to 4,500,000 gallons daily. By February 19th the ground-water had begun to fall at a point 850 feet from the line of wells, measuring at right angles, and by February 26th the cone had extended to a point 2,000 feet distant and about 12 feet higher than the water in the wells. On May 15th the slope of the ground-water at 2,000 feet distant was one in 800. By November the cone had extended to something over 3,000 feet. It was determined during these studies that if the ground-water should be drawn to a distance of 16 feet below its ordinary level at the wells the influence of the wells would extend at least 3,500 feet. This would give an area of influence for these gang-wells not much exceeding one square mile if the ground had been level; but it rose to the northward, and the permanent ground-water rose with it at a rate of about 10 feet to the mile, so that the ground-water was constantly moving southward to the ocean through the sand and gravel. This water coming within the limit of influence of the wells added largely to the yield. It would appear that if the water in such a line of gang-wells can be lowered 25 feet below the natural level of ground-water, such wells will be

able to yield up to their maximum capacity. If the pumps are set at about the level of permanent ground-water, therefore, the maximum capacity of the wells can be obtained by suction under such conditions as we have assumed. Gang-wells will approach a limit of draft corresponding to that shown in Fig. 20 more or less closely, but, as in the case of a single well, this will be considerably modified by the replenishment due to rainfall. Such gang-wells as above described have in some cases on Long Island lowered the water to an appreciable extent at a distance of nearly one mile.

The conditions to which we have above referred are typical, and it must not be forgotten that they do not obtain even on Long Island, where the material approaches homogeneity fairly well for a moderate depth. It still varies widely from the typical condition assumed, and it is found that the water traveling down the southern slope gathers itself together in more or less well-defined underground streams.

Our collections of data and our studies have not proceeded far enough as yet to give definite results, but the foregoing is to be considered tentative and illustrative of the method by which we hope to produce results which may be of actual service in developing underground water-supply. The judgment of the engineer must always be finally depended upon for a particular locality. This, however, is true of many formulæ which are found of great practical use to the engineer, although in their final application much depends upon the exercise of his judgment.

PART V.

**The Pine Belt of Southern New Jersey,
and Water-Supply.**

BY C. C. VERMEULE.

(183)

GEOLOGICAL SURVEY OF NEW JERSEY.
A MAP OF
NEW JERSEY
1898.

Scale of Miles.
0 5 10 15



Southern New Jersey Pine Belt.

The line which divides the deciduous timber from the coniferous, forming the northwesterly border of the pine belt, was carefully examined and surveyed during the autumn. There is generally quite a broad belt of mixed timber along the border, so that we have traced upon the accompanying map both the northwesterly limit of the timber which may be said to be practically all pine, and the southeasterly limit of that which is all deciduous. Between these lines is the belt of mixed deciduous and coniferous timber to which we have referred, varying in width from a few yards to eight miles. There are, however, isolated areas included within the pine district which are much mixed with oak. Some of the older residents of the district are of the opinion that, generally speaking, there is much more oak than there was forty years ago. Oak usually comes up to replace pine which is cut off, excepting where the land has been cultivated for a time. In abandoned clearings the growth is exclusively pine.

East of the Southern Railroad of New Jersey, in Monmouth county, the mixed belt is mostly oak and chestnut of all grades, from brush up to merchantable timber. The latter term is here used to include timber suitable for heavy railroad ties as well as larger trees suitable for sawing into dimension timber. In the Hominy hills, south of Colt's Neck, it is mostly pine, little of merchantable size. Westward from Farmingdale to Charleston Springs it is quite evenly mixed, the merchantable timber being confined to the vicinity of the highway from Lakewood to Freehold. From Charleston Springs to Horners-town the line between pine and oak is quite sharply drawn, the pine being generally small and the oak of merchantable size. Indeed, the heaviest oak timber seen was in this vicinity. Proceeding southwesterly, the mixed belt retreats eastward to Collier's Mills, and the oak lands west are, as usual, well cleared.

Southwesterly from Collier's Mills beyond Brindletown, pine predominates in the mixed belt and is of larger size, about one-half

merchantable. Thence to New Lisbon it is more evenly mixed, but of smaller size, brush and light timber.

A good deal of land has been cleared just west of Asbury Park, but thence to New Lisbon there has been practically no clearing during the last fifteen years. Thence to Clayton there are a few new clearings in and near the mixed belt, but south from Clayton, to Elmer, they are more numerous, and south of Elmer a good deal of territory has been cleared and brought under cultivation, especially around Rosenhayn, between Bridgeton and Millville, and east of Fairton.

Continuing from New Lisbon southwesterly, we find very little merchantable timber. Southeast from Medford, at Indian Mills and Tabernacle, there is a notable southeasterly encroachment of the oak and clearings, upon the pine belt. The mixed timber here has been cut very close, and what remains is mostly brush. It is little better anywhere southwest as far as Williamstown. Oak brush predominates throughout, accompanied by much small timber, and especially just south of Clementon. The general absence of good timber near the clearings here is probably attributable to close cutting for firewood and other local uses. The same conditions obtain near Elmer, Bridgeton and eastward, and especially around Rosenhayn. Wherever there is much clearing most of the older timber has been cut out, leaving brush from two to fifteen feet high.

From Williamstown to Elmer, however, there is much better timber in the mixed belt, especially to the northeast of a line joining these two places, oak prevails, and there is a fair proportion of merchantable timber. About Janvier there is the same severe cutting that has been noted above.

Southeast of Alloway, in Salem county, and considerably to the westward of the general limit of coniferous forests, there is an isolated tract of timber well mixed with coniferous trees, although oak preponderates. There is a fair proportion of merchantable timber here, although it is not so good as the exclusively deciduous timber which surrounds it, the latter being scattered over a highly cultivated country, in small groves and hedgerows.

Generally in the foregoing description we have used the term "oak" as synonymous with "deciduous." No real error can result from this, for it is true that oak largely outnumbers all other kinds in the deciduous forest. Chestnut occurs also, however, well scattered throughout, from Asbury Park to Delaware bay.

A plantation of grafted chestnut trees was observed in Camden county, just south of Point Pleasant and about three miles southeast of Spring Mills. Among the coniferous trees a few scattering white pines were noted between Asbury Park and New Egypt.

Generally speaking, however, the coniferous trees consisted of white cedar in the swamps and two varieties of pine on the upland; viz: the common pitch pine (*P. rigida*) prevailing everywhere, and the hemlock pine (*P. virginiana*) which was first observed, when going southwest along the pine border, at a point east of Pemberton; also scattering trees were seen about Tabernacle and Indian Mills. At Cedar Grove, on the Cohansey, this species became more numerous, and between Bridgeton and Millville nearly all of the pines seen were of this kind.

It will be noted that the map indicates Maurice river as the western limit of the exclusively coniferous forest in Cumberland county. Not only is there a liberal mixture of deciduous trees west of this limit, but it has been stated that new clearings are more numerous and that *P. virginiana* prevails instead of *P. rigida*.

An inquiry was begun to determine the extent of clearing within the pine belt in order to establish present tendencies. A careful survey of the clearings was made when the topographic survey was executed. In the pine belt this was from 1883 to 1886, and most of the work was done in 1884 and 1885. A re survey at this time, therefore, will show the extent of clearing which has been done in the interval. Such a re survey has been made at Hammonton, and a map showing the results has been prepared. It shows that the forest area has been very materially diminished. The same is true of most of the country along the New Jersey Southern Railroad all the way from Hammonton to Bridgeton, especially at Carmel, Vineland and Rosenhayn. Along the lines of the Camden and Atlantic, and Atlantic City railroads, from Hammonton to the coast, the same conditions prevail. Other centers of clearing are Richland and Woodbine. Most of the clearing is south of Mullica river—there is little or none north. A few clearings have been allowed to grow up again, but not enough to appreciably affect the tendency to increase the cleared land.

It is said that ten years ago the cost of clearing and grubbing this land, ready for the plough, was about \$25 to \$35 per acre, but that it can now be done for from \$10 to \$15, and the new ground can be broken up for about \$8 per acre.

If present tendencies continue it seems plain that most of the land west of the limit of exclusively coniferous forest will be cleared up, or at least the forest will be divided up into small parcels.

Within the pine belt there will be a broad belt of cleared land extending from Hammonton to Absecon, another along the New Jersey Southern Railroad, southwest of Hammonton, and the extension of the large cleared area at Vineland and southerly to Woodbine will leave the pines divided into two tracts, the one lying in the Great Egg Harbor watershed and the other north of Mullica river, extending to Lakewood. Within the limits of these areas, which we have tinted a dark green on the accompanying map, there is no observable tendency to extensive clearing. The forest is almost unbroken. It will be observed that these are also the tracts where the severest fires rage at present. It may be suggested that these are proper fields for something like systematic forestry, or at least for the inauguration of permanent measures to prevent fires. The remainder of the pine district is gradually but very steadily being broken up into small parcels by clearings, in such a way that fires will, in time, cease to be of very great importance. The tendency to clear up and bring under cultivation the better soils of the pine belt must be regarded as fortunate from every point of view. These better soils will produce more under cultivation than they possibly could in forest, and the breaking up of this great belt of timber into sections will make it easier to deal with fires. There is an unfortunate prevalence of fires from carelessness about the clearings, but there seems to be existing legislation enough to deal with this question if the laws are enforced.

The importance of preserving some belts of timber throughout this ground that is being cleared up should be emphasized, however. They will be very valuable as wind-breaks, and it is quite possible that there will be a material change in the mildness of the climate of this section unless a reasonable amount of timber is preserved. The importance of leaving a good belt of timber along the streams is especially great. This needs to be done, especially in the case of the Great Egg Harbor and Maurice rivers, as it is on these watersheds that most of the clearing is being done. The better soils here are usually on the higher ground, so that there should be little opposition to preserving the forests near the streams. These streams are now developed to an important extent for water power, and are likely to be still further developed in this direction. They have also a possible

future value for water supply, and the preservation of such bordering belts of timber would be a valuable safeguard in maintaining their purity. At least 75 per cent. of their watersheds can be cleared and brought into preservation without seriously endangering the streams, because of peculiarities which were pointed out in the Report on Water-Supply. The primary reason is that the rain falling upon the sand and gravel soil sinks at once into the ground and thence finds its way gradually to the stream lines. To appreciate the great difference in this respect from the red sandstone or Highlands district of Northern New Jersey it is only necessary to compare the topographical maps of the two sections. In the north there will be observed a very large number of small tributaries, and generally one cannot go far in any direction without coming to a running brook, but in the pine belt there are quite large areas of the higher ground with no visible streams.

It may be well to point out further the relation of these pine forests to the question of water-supply. Included in those areas of forest which we do not consider as likely to be cleared up and brought under cultivation, and which I have colored a darker tint on the accompanying map, are a large number of streams which may afford valuable sources of supply in the future for Southern New Jersey towns. The watersheds so included are shown in the following table, together with their estimated capacity.

	Estimated capacity in gallons, daily.	
	Without storage.	With storage.
Toms river above Toms River village.....	27,500,000	112,000 000
Cedar creek	9,370,000	31,900,000
Forked river ..	2,470,000	8,400,000
Manahawkin creek.....	3,300,000	11,200,000
Westecunk creek	3,530,000	12 000,000
Wading river above Harrisburg.....	27,600,000	109 000,000
Mullica river above Batsto.....	37,200,000	147,000,000
Patcong creek above Bargaintown.....	3,200,000	10,800,000
Babcock creek—Mays Landing.. }	3,965,000	12,100,000
Watering race— “ “ }		
South river above Monroe.....	3,190,000	10,800,000
Stephen's creek above Estellville.....	1,695,000	6,000,000
Tuckahoe river above head of river.....	4,840,000	17,100,000
West creek, Cape May county, above mill-pond.....	1,180,000	4,000 000
Manumuskin creek.....	6,380,000	21,700,000
Manantico creek.....	6,380,000	21,700,000
North Branch of Rancocas creek above New Lisbon,	17,800,000	55 000,000
South Branch of Rancocas above Vincentown.....	9,000,000	25,900,000
	168,600,000	615,700,000

In the table above there is first given the capacity of the stream to supply water in its natural condition without storage, while the last column gives its capacity when fully developed by storing the surplus waters of the wet season and using them to feed the stream during the period of low water. The capacities given in the first column can be obtained at slight cost by simply setting up a pumping-station on the bank of the stream, but the necessary storage to obtain the full capacity would cost much money.

We pointed out in the Report on Water-Supply those valuable characteristics of the East Jersey watersheds which tend to preserve a higher degree of purity and wholesomeness. The fact that the rainfall sinks at once into the earth and that a rush of water over the surfaces of the streams is practically unknown is the most important one, for it insures perfect natural filtration and avoids the carrying of surface impurities into the stream waters. Now, if these watersheds can be preserved in their present condition, that is, well covered with pine forests, they afford typical gathering grounds for domestic water-supply. It is true that these waters are slightly colored, but the color is clear and by no means disagreeable. It is also much less than it appears to be in the stream when the water is dipped up from the stream in a glass or pitcher, and the wholesomeness of this clear water is well known. The color is derived principally from the cedar swamps. The water is very agreeable to the taste, decidedly more so than most of the well-waters of that section.

We will point out briefly why we believe that these streams are likely to be needed in the future and why it would consequently be desirable to preserve them in a wholesome condition for future use. In the Report on Water-Supply of 1894 we pointed out that the Highlands watersheds, which we recognized as pre-eminently the gathering-grounds for public water-supply, were capable of furnishing a daily supply of 446,200,000 gallons (see page 313). On page 319 of the same report it was shown that the use of water for the supply of cities and towns within the State had increased from about 49,000,000 gallons daily in 1882 to 108,000,000 gallons daily in 1894, and we followed this with an estimate of what would be needed in the future if the supply should increase, not at the rapid rate shown for these twelve years, but at the same rate as the increase of population in our cities. This estimate is reproduced herewith :

	Population Supplied.	Gallons Daily
1894.....	1,114,403	107,840,361
1904.....	1,560,000	151,000,000
1914.....	2,180,000	211,000,000
1924.....	3,050,000	296,000,000
1934.....	4,270,000	414,000,000
1944.....	5,980,000	580,000,000

Undoubtedly the Highlands watersheds will all be pre-empted within the period covered by this estimate by the northern cities, for these cities do not wait till they actually need the water, but wisely endeavor to control a sufficient quantity for their reasonable future needs. Thus the city of Newark has taken from the Pequannock a supply of fifty million gallons daily, although she is using only about half that amount at present, and even now this city is fully alive to the fact that it is very desirable to secure a still larger supply in the near future. Jersey City is also intending to make a contract, which will secure a supply of seventy million gallons daily from the Rock-away river, so that these two cities alone will already have taken nearly one-third of the entire available supply in the Highlands. The southern towns have their immediate wants provided for by existing water-works, and to a very considerable extent by wells, but as they increase in population many of them must look to other sources. We have compiled a table of southern New Jersey towns which are now supplied with water, which table shows the consumption of water in 1895, and also the increase of population of these places for the ten years preceding. We have included New Brunswick and Perth Amboy in this list, although they are not strictly within the South Jersey district, but both of these places are now using what are practically southern New Jersey stream waters, that is, waters having the general characteristics of these waters of the pine plain included in the above table :

WATER-SUPPLY OF SOUTHERN NEW JERSEY TOWNS.

	Population,		Source of Supply.	Gallons of Water used Daily, 1895.
	1885.	1895.		
Asbury Park.....	2,124	3,761	Wells.....	500,000
Atlantic City.....	7,942	18,329	Wells.....	4,500,000
Atlantic Highlands.....	.....	1,715	Wells.....	109,000
Beach Haven.....	.....	230	Wells.....	50,000
Beverly.....	1,973	1,924	Delaware River.....	.....
Bordentown.....	4,683	4,185	Delaware River.....	500,000

	Population, 1885. 1895.		Source of Supply.	Gallons of Water used Daily, 1895.
Burlington.....	6,653	7,844	Delaware River.....	450,000
Bridgeton.....	10,065	13,292	Wells and streams...	630,000
Camden.....	52,884	63,467	Wells.....	12,000,000
Cape May City.....	1,610	2,452	Wells.....	350,000
Cape May Court House (new), .....	.....	.....	Wells.....	.....
Clayton (new).....	2,399	2,130	Wells.....	127,800 <i>e</i>
Collingwood.....	.....	1,020	Springs.....	25,000
Egg Harbor City (new).....	1,317	1,557	Wells.....	93,000 <i>e</i>
Freehold	2,124	3,157	Wells.....	150,000
Glassboro (new).....	2,377	2,664	Wells.....	159,800 <i>e</i>
Gloucester City.....	5,966	6,225	Springs and streams,	500,000
Haddonfield.....	1,950	2,580	Stream.....	25,000
Hightstown.....	1,608	1,875	Wells.....	25,000
Keyport.....	3,063	3,386	Wells.....	200,000
Lakewood.....	.....	2,201	Metedeconk River...	60,000
Long Branch.....	5,140	7,333	Stream.....	1,300,000
Longport.....	.....	.....	Wells.....	.....
Maple Shade.....	.....	.....	Well.....	.....
Medford.....	992	1,989	Stream.....	30,000
Merchantville.....	741	1,339	Stream.....	46,600
Millville.....	8,824	10,466	Maurice River.....	650,000
Monmouth Beach.....	.....	.....	Stream.....	.....
Moorestown.....	1,600 <i>e</i>	2,300 <i>e</i>	Stream.....	250,000
Mount Holly.....	5,006	5,750	Rancocas Creek	280,000
New Brunswick.....	18,258	19,910	Lawrence's Brook...	1,600,000
Ocean City.....	465	921	Wells.....	.....
Ocean Grove	1,177	3,580	Wells.....	186,300
Palmyra.....	.....	2,310	Wells.....	120,000 <i>e</i>
Pemberton.....	844	816	.....	.....
Perth Amboy.....	6,311	13,030	Tennent's Brook....	2,000,000
Red Bank.....	3,186	4,888	Wells.....	200,000
Riverton.....	.....	1,250	.....	60,000
Salem	5,516	6,337	Wells and streams...	400,000
Sea Isle City.....	558	424	Well.....	75,000 <i>e</i>
South Amboy.....	4,054	5,571	Tennent's Brook....	40,000
Stockton.....	3,709	8,010	Wells.....	480,000
Vincentown (new).....	777	722	Rancocas Creek	40,000 <i>e</i>
Vineland.....	3,170	4,126	Wells.....	125,000
Wenonah.....	287	473	Spring.....	30,000 <i>e</i>
West Asbury Park (new).....	.....	.....	Wells.....	.....
Wildwood.....	.....	109	Wells.....	25,000 <i>e</i>
Woodbury	3,278	3,853	Mantua Creek.....	300,000
Woodstown.....	.....	1,470	Wells	30,000
Total.....	182,631	250,971		28,722,500

The population supplied with water in southern New Jersey increased about forty per cent. in this decade, from 1885 to 1895. The increase in water consumed was much greater, but estimating it at forty per cent. in ten years, it is clear that the time is coming when these potable waters will be utilized.

PART VI.

I.

Fire-Brick and Clay Industry.

II.

The Iron-Mining Industry.

BY GEORGE E. JENKINS, C. E.

(195)

I.

The Brick and Clay Industries in the State of New Jersey.

In the United States Geological Survey Report, the State of New Jersey is given the fifth place in the output of clay products, and, the canvass of last year showed, the clay-using industry is one of the most important in the State, because of the position of the State in relation to the large eastern cities and its supply of raw material. In addition to an abundance of clay suitable for use in making common brick, which is scattered so promiscuously throughout the State, and consequently making it possible for nearly every town to have its own brick-yard, the State possesses large deposits of high-grade clays, suitable for use in the highest class of manufactured product. In the section of the State known as "The Clay District," which comprises the deposits at Woodbridge, Perth Amboy and South Amboy, clay has been mined and used in manufacturing for years past, but the large deposits in the Southern-central and Southern parts of the State have been availed of only in the past few years and large industries have grown up where only a short time ago nothing but pines and sand were in evidence.

The results of this year's canvass shows that, with one exception, every brick-yard that was in operation last year has been a producer, and several heretofore idle yards have resumed operation.

The capacity of many of the yards has been run to its fullest extent, and at the close of the year many of these had sold their entire product at an advance in price. These conditions are the results of the general advance in business and especially the increase in building which has been going on in the cities throughout the State, and also to the strike which took place in the brick-yards of the Haverstraw district along the Hudson river.

The manufacturing plants engaged in making fire-proofing and other structural material, as well as the terra-cotta works, have felt the demands from the building trade.

There are eighty-two common brick-yards in the State, of which five have been non-producers during the year.

In pressed and ornamental brick there are twelve firms, all of which have been very active producers. There are ten firms engaged in manufacturing fire-proofing and other structural material.

In enameled brick and tile six firms have been producers, with one other firm about to enter the field.

Eleven firms have been engaged in manufacturing fire-brick.

The results of the canvass of the clay-working industries in the several counties of the State are comprised in the following notes:

SUSSEX COUNTY.

There is but one brick-making plant in this county, located at Newton, and the manufacture is principally confined to the demands of the Newton building trade. The brick is of excellent quality and if the yard was more favorably located, with reference to shipping facilities, the quality of the product would soon find a market in other parts of the country.

Mr. Frank Losey owns and operates the plant, and no changes have been made in plant or yard since the last canvass.

PASSAIC COUNTY.

The manufacture of brick is confined to the southwesterly part of the county, in Wayne township, along the line of the Morris canal and in close proximity to the Passaic river, and the following firms and individuals have been making brick in the past year:

SINGAC BRICK CO., LITTLE FALLS

W. H. Roberts and W. Beatty, members of firm.

The clay deposit is of ordinary common brick clay and is located on the south bank of the Morris canal and north of the road leading from Totowa to Two Bridges. The plant has been increased by the addition of a new Wildes brick machine, and the product for the

year was very much larger than last year, the market being principally in Paterson and neighboring districts.

STANDARD BRICK COMPANY.

Alex. McKorgan, President.

The plant is located at Mountain View and the main office is at No. 492 Broad street, Newark, this city furnishing the principal market for the yard's product. In addition to the equipment given last year the firm has added an additional tempering wheel and the capacity of the yard is to be doubled. The plant was run to its full capacity in the past season.

JOHN M. POWERS.

Office, No. 226 Marshall street, Paterson.

This plant is located at Singac, and is probably one of the oldest plants in the county, but the low prices prevailing in the brick market in the past three years have been such as to militate against this plant's operation.

GEORGE ADDY, PATERSON.

The clay-bed and yard located at Mountain View has been worked energetically during the past year, and the owner has sold more brick than he has been able to make. Clay has been mined from this bed for about forty years, and as the deposit is now worked to considerable depth the task of draining the pits is considerable, and in order to accomplish this in a more economical way a new windmill has been added to the plant for the purpose of effecting the drainage. The present owner has sold this plant to Mr. Peter Ulrich and Joseph Ischwald, who take possession on February 1st.

BERGEN COUNTY.

The clay deposit from which the ten different yards of this county obtain their clay is located along the Hackensack river at Little Ferry and Hackensack, and the making of common brick is a very extensive industry. The clay-beds vary in depth from twenty feet at the northerly extent of the deposit to ninety-eight feet deep at Little Ferry. The clay is well adapted for the manufacture of sanded

porous building-brick of uniform color and strength, and which stands in high repute among large building operators in the large cities. The distance to New York is only seven miles in an air line, but in order to reach this market thirty-one miles has to be traveled, and although the Hackensack river affords a waterway of an almost uniform depth of thirty feet, this admirable artery of commerce is very seriously handicapped by the numerous drawbridges of the many railroad lines which now cross at such a low elevation. In consequence of these obstructions the shipping has to be done almost entirely by barges and steam-tugs, and as the cost of towage is high, the otherwise cheap facilities for shipping are minimized and the natural advantages as to closeness of market afford no benefits to the manufacturers.

In the manufacture of brick the ten yards of this district pursue the same uniform method in tempering the clay, in the use of soft mud type brick machine and in the burning of the brick. With the exception of the Mehrhof Brick Company, all use wood fuel and burn in temporary arched kilns. The product for the year has been over 60,000,000, showing an increase over last year's product of nearly 90 per cent., and the amount of capital invested is about \$265,000. The following firms have made brick in the past year :

M. B. & L. B. Gardner, Hackensack.
Charles E. Walsh (two yards), Hackensack.
Edward Schmultz, Hackensack.
James W. Gillies, Hackensack.
J. & W. Felter, Little Ferry.
Mehrhof Brick Company, Little Ferry.
Nicholas Mehrhof & Company, Little Ferry.
Philip Mehrhof, Little Ferry.

In addition to the manufacture of common building brick, Bergen county has one firm at Maywood engaged in manufacturing art tile and the firm is known as "The Maywood Art Tile Company," Gustaf S. Jaeger, President; Ernest Bilhuber, Secretary and Manager. The main office and plant is located on the New York, Susquehanna and Western Railroad at Maywood. The manufactured product consists of plain, glazed enamels, including border tile and vitrified floor tile. In the manufacture of this product ball clay from the Perth Amboy clay district and imported English China clay are used. The plant consists of one boiler and two engines. Seven hand-presses, having a total daily capacity of 2,400 to 3,000 pieces

of tile per day, are in operation. The tile are burned in up draught kilns, using hard coal fuel, and the total capacity of the five kilns is 7,000 square feet. From 46 to 50 men are employed, the majority of whom are skilled laborers. The market is in the principal large Eastern cities.

WARREN COUNTY.

The brick and clay industry in this section embraces two brick-yards and the extensive Terra Cotta Lumber Manufacturing Plant, at Port Murray.

The brick-yard of David E. Cole, at Karrsville, is a small primitive establishment which supplies the limited demands of the surrounding farming districts. The clay deposit is common brick material of limited area and depth. Only hand-made brick are manufactured.

JOHN C. BENWARD, WASHINGTON.

This establishment is a very old one. The plant and clay deposit were fully described in the last year's report. The bricks are all hand-made and are burned in open, temporary, arched kilns using wood fuel. Only the local market is supplied, but the product for the past year has been ninety per cent. greater than in the past three or four years.

PITTSBURG TERRA-COTTA AND LUMBER COMPANY.

This plant has been in active operation all the year making a large output of porous terra-cotta, dense tile, plain and ornamental building blocks, hollow, pressed and paving brick. There has been no addition to the plant since the last canvass. The product is shipped to the large cities and is used in "modern fire-proof" buildings.

MORRIS COUNTY.

There are only two brick-yards in this county, and during the year but one of these has been operated.

SILAS L. ARMSTRONG, MORRISTOWN.

This plant has been in active operation during the season, supplying brick to Morristown and Madison.

In December, Mr. Armstrong died, and the business is now conducted by Mr. Fred L. Armstrong.

WATNONG BRICK COMPANY, MORRISTOWN.

Fred Schmidt, Treasurer.

Preparations are being made to put this plant in operation, after being idle for the past three years.

HUNTERDON COUNTY.

The following firms are engaged in manufacturing in this county :

H. E. PEDRICK, FLEMINGTON.

This plant has been overhauled during this year, and a new "Martin Brick Machine" driven by steam-power has been added, as well as a new plant for drying the green brick, and new permanent walled kilns, using hard coal fuel, have been erected. The capital has been increased to \$8,000, and the number of hands employed increased to seventeen ; the product doubled.

THEODORE O. DANIEL, LAMBERTVILLE.

This plant has been inoperative for the past two years, but is not abandoned.

FULPER BROS. & CO., FLEMINGTON.

This firm failed and made an assignment in February, and the property is now owned by Mrs. Tunnison ; G. W. Fulper renting and operating the plant, making stoneware and using South Amboy clays.

SOMERSET COUNTY.

JAMES C. ROSS, SOMERVILLE.

This brick-making plant is operated by William Ross, Jr., agent. During past years the works have been operated by horse-power, but plans have been made to change to steam-power and put in new "Monarch" machines, made at Wellington, Ohio. The year's product was about the same as heretofore. The Ten Eyck plant is still owned by Mr. Ross and it has not been in operation during the year, and the plant, which contains two "Wildes" machines, operated by steam-power, is for sale.

R. A. BOYCE, NORTH PLAINFIELD.

The property upon which this yard is located is owned by Sylvester Scribner, but leased by R. A. Boyce, whose office is in Somerset Hotel, Plainfield. The clay-banks are located at the brick-yard north of Green Brook and near the foot of First Mountain, about half-way between Plainfield and Dunellen, in Somerset county. The deposit is from four to eight feet deep, with a light covering of shaly earth. The clay is of a short and fibrous character and requires the addition of anthracite coal-dust in the proportion of one bushel to the thousand brick in order to insure proper burning and increase the porosity of the brick. The plant consists of one tempering-wheel and pit and one Martin brick-machine operated by horse-power. The capacity of the plant is two million per year. The "firing" is done in temporary arches, using wood fuel. During the season twenty men are employed. The product is sold in the local market at Plainfield.

D. HAND & SON, NETHERWOOD.

This firm operates two yards, one under lease from Mrs. Peterson, which is located on Mountain avenue, in North Plainfield, and a second yard at Dunellen, in Middlesex county. The clay is an ordinary brickmaking material, from 3 to 4 feet deep, and is somewhat short in character. The plant on Mountain avenue is operated by horse-power, and consists of one tempering-wheel and pit and one "Horton" machine. The brick is burned in temporary kilns, using

wood fuel. The clay bank at Dunellen is of the same character and depth as the above, and the plant consists of two Wildes machines, driven by horse-power. Forty-five men find employment during the season. The market is entirely a local one.

EXCELSIOR TERRA-COTTA COMPANY.

Rocky Hill.

New York Office, No. 105 East 22d Street.
H. W. Powell, Gen. Manager.

The supply of clay used by this firm is at Ten Mile Run and consists of a deposit about five feet deep of buff terra-cotta clay, from which ornamental architectural terra-cotta is made. The plant is located by the side of the Delaware and Raritan Canal, about one mile north of the Rocky Hill depot. It consists of two boilers of one hundred horse-power and one engine, which furnishes power for driving two horizontal pug-mills having a daily capacity of 50 tons each. There are four Muffle kilns of a capacity of 30 tons each. Eighty men are employed, most of whom are skilled laborers.

UNION COUNTY.

JOHN J. REED, NETHERWOOD.

No. 825 Leland Avenue.

The First National Bank of Plainfield owns nine acres of clay-land and leases the same to Mr. Reed. The deposit has been found to a depth of twenty-six feet and is a very tough, stiff-working clay, requiring a liberal mixture of loam in order to prevent shrinkage, increase the porousness and lighten the brick. The plant, consisting of two tempering-wheels and two Wildes machines, is operated by steam and has a capacity of thirty thousand per day, but only a small percentage of the capacity is manufactured, as only the local market is supplied. Sixteen men are employed and the amount of capital invested is five thousand dollars. The brick is burned in temporary arches, using wood fuel.

JACOB HAMMER.

No. 626 Elizabeth avenue, Elizabeth.

The clay-bank and yard is located on south Front street and Bayway, Elizabethport, and consists of about six acres of clay-land in which a deposit of common red clay of a thickness of from six to ten feet is worked. The plant consists of one engine, 80-horse-power, and a boiler of 100-horse-power; these operate two tempering-wheels and two Wildes brick machines. Wood fuel is used and the brick is burned in temporary arches. During the last twenty-five years this yard has been in operation supplying brick to the building trade of Elizabeth.

P. MACHERIONE, BERKELEY HEIGHTS.

The Mutual Life Insurance Company of New York owns about fifty acres of clay land, and Mr. Macherione operates the plant here located under lease. The deposit has been found to a depth of thirty feet and is covered with from one to two feet of soil. It is dark, almost black in color, but of good quality and free from gravel and very strong, requiring the use of coal dust.

The Mutual Life Insurance Company owns this and another small adjoining yard, but only the above works have been making brick in the past year.

MERCER COUNTY.

The brick and tile product of Mercer county is concentrated principally at Trenton, and the following firms have been producers during the past year:

TRENTON FIRE-BRICK COMPANY.

G. R. Frost, President; C. A. Pope, Treasurer; F. C. Lowthorp, Secretary.

The manufactured product consists of fire, pressed, front, paving brick, and common building brick. The clay used in the manufacture of this product is purchased from different parts of the State and the firm owns no clay-banks. The plant, which is driven by steam-power, consists of two pug-mills and Penfield and Auger Machines, as well as six hand and one steam two-mould re-press machines, and

one single-mould press. The drying is done by steam and the plant is operated all the year. There are eight down-draught round kilns, four of which have a capacity of 60,000 each, and the others 40,000 each. The total capacity of the plant is 25,000 per day, and fifty men are employed.

H. C. KAUFER & CO.

The plant and clay-beds are located on Princeton avenue, near the city line, and this company controls forty acres of clay land. The clay is from three to ten feet deep and of good quality, and burns to a bright red, making excellent front pressed brick. The plant consists of a twenty horse-power boiler and engine which operates four temporary wheels. There are four square, permanent, walled kilns of the "Dutch-oven" pattern, using hard coal for fuel. The capacity is 135,000 to each kiln. Seventy-five to eighty-men are employed during eight months in the year.

PETER FELL COMPANY.

Charles Reichert, President ; James Tams, Treasurer.

This company controls seventy-four acres of clay deposit on Princeton avenue, but the clay is not at all regular in strata and there is much variation in its depth. It will average nine feet, and in texture it is very stiff, requiring an addition of one third loam in order to give the proper porousness to the brick. It is treated by tempering-wheels, four of which are operated. A crusher and pug-mill are also in use. The product is both hand and machine-made, using a Penfield machine, which has a capacity of thirty thousand a day. The burning is done in four "Dutch-oven" kilns, using hard coal fuel, and the capacity of each is 180,000. This is a pallet yard, and the sheds have a capacity of 200,000. Both common and red front pressed brick are made, and the latter is all hand re-press.

DONAHUE & NOLAN.

Brick-yard is located on Kirkbride avenue, and the clay-bank at Ewingville. The firm controls a deposit of 133 acres, and it has an average depth of six feet. It is a superior brick-clay. The plant is operated by one 30-horse power boiler and engine, furnishing power

to three tempering-wheels. The brick are all hand-moulded and hand re-press red front brick. There are four kilns, of the "Dutch-oven" pattern, using hard coal fuel.

They each have a capacity of 150,000. The product manufactured consists of red front pressed and common brick. Sixty men are employed. The market is principally in New York city.

APPLEGATE & COMPANY.

Manufacturers of red front and common brick, and the plant is located on Ingham avenue. The clay is obtained from Woodbourne, Pa.

The plant is operated by 25-horse-power boiler and engine, driving three tempering-wheels. All brick are made by hand. The pressed brick are all hand repress and seventy men are employed during the season. There are four kilns having a total capacity of 80,000 brick.

W. W. FELL, BRICK YARD.

The plant is located on Pennington avenue and has not been producing during the year, but Applegate & Company now own the plant and it will be put in operation next spring.

S. B. WALTON, BUFF BRICK COMPANY.

The clay deposit and plant is on Ingham avenue and there are thirty acres of clay from two to four feet deep. As there is considerable gravel running through the deposit the product has to be ground in an E. M. Freese crusher, and three tempering-wheels prepare the clay for hand-moulding. The kilns are one down-draught and two up-draught, using hard coal for fuel. The total kiln capacity is 60,000. During the season thirty-five men are employed.

R. M. DRAKE & CO.

This firm began business in the spring of 1898, making only pressed front brick. The supply of clay is purchased from dealers at Perth Amboy and Mercerville, near Trenton. The clay is passed through a Mackenzie pug-mill and the whole product consists of hand-

made pressed front brick. There is one Dutch kiln using soft coal and it has a capacity of 15,000 brick. Ten men are employed.

The total product from the Trenton yards amounts to 9,700,000 common brick, 6,000,000 pressed and paving brick and 2,700,000 fire-brick.

MIDDLESEX COUNTY.

As what is known as "The Clay District" of the State is embraced almost entirely within the limits of this county, all the large clay manufacturing works are here located and make up an industry of very large proportions.

The following firms are found in this district :

M. D. VALENTINE & BROS. CO., WOODBRIDGE.

Manufacturers of fire-brick, have two large plants, one at Woodbridge and another at Valentine Station, on the Lehigh Valley Railroad.

The firm owns and controls large areas of clay land and are also large purchasers. The plant has twelve kilns of a capacity of thirty-five thousand brick each, and the total annual capacity of the works is eight million per annum.

SALAMANDER WORKS, WOODBRIDGE.

The extensive plant of this company was destroyed by fire over a year ago and no product has been made in the past year, and the property is offered for sale.

JAMES E. BERRY.

(Successor to W. H. Berry & Co.)

After being idle for a considerable period this plant was again put in operation in October, 1897. Fire-bricks in their many forms are manufactured, and the plant consists of two tempering-wheels and one brick machine, a number of hand re-press machines, and a large product is made by hand in special shapes and sizes. There are four round up-draught kilns, having a capacity of twenty-two thousand each. The total capacity of the plant is 2,100,000 per year, and twenty men are employed. The operator buys clay from the dealers in this product at Woodbridge.

THE STATEN ISLAND CLAY CO.

F. A. Handby, Superintendent.

This plant is located on the line of the Pennsylvania Railroad, about one-quarter of a mile south of M. D. Valentine & Bros.

The output consists of fine brick, pressed and ornamental brick and structural material.

HENRY MAURER & SON.

The very extensive plant of this firm is located at the junction of the Central R. R. of N. J., and the Penn. R. R., and on the south bank of the Woodbridge creek. Fire-proof building material in its numerous varieties of pattern and style is made in large amount, and the plant consists of a nest of Babcock and Willcox water tubular boilers, of 525 horse-power, three Corliss engines, of 150 horse-power each, four tile machines of a daily capacity of forty-five tons each, and four wet pans of like capacity in which the clay is prepared for the machines. The hollow-brick and terra-cotta building material are burned in Hoffman continuous kilns, of which there are two, and each has a capacity of 480 tons. These kilns are very expensive in first cost of construction, but the saving of lost heat and the consequent reduction in fuel-consumption and labor, and the saving of time, more than justifies the first outlay of capital. These kilns generate a degree of heat up to from 2,200 to 2,500 Fahrenheit.

The fire-brick plant consists of two pug-mills, two "chasers" or mixers and four soak-pits, and the daily capacity is twenty thousand. A large number of special designs and shapes are moulded by hand. There are two moulding machines having a capacity of ten thousand each, and nine re press machines, a steam dryer having a capacity of ten thousand brick in twenty-four hours. The fire-brick are burned for one hundred and twenty hours, at a temperature of 3,200 degrees, in square down draught kilns. There are five of these kilns in use, having a capacity of 35,000 each, and, in addition to the two continuous kilns, the plant has six square up draught kilns of a capacity of from 60 to 120 tons per kiln.

In connection with the terra-cotta plant, there is a crushing and grinding plant for preparing "grog," which has a daily capacity of fifteen tons.

The common building-brick are made by Martin's sanding soft

mud machine, and as the product is made from the refuse fire-clay from the terra-cotta and fire-brick department, the bricks are hard-burned and dense but possessing great porosity, and "set" well in the mortar. From sixty to seventy thousand tons of clay are used by the firm in a year, and a large force of men is employed. The clay is obtained from the firm's own banks in the Perth Amboy clay district.

C. W. BOYNTON, SEWAREN.

Manufacturer of drain tile and hollow brick. The plant has 75 horse-power boiler and engine, but only 35 horse-power is now used in driving the tile machines for making hollow brick and tile and running one Penfield crusher and elevator and a tile machine. There are four down-draught kilns, 14 x 6 feet, having a capacity of 40 tons each. Brick machines of 80 tons capacity per day.

C. PARDEE WORKS, PERTH AMBOY.

New York Office, No. 15 Cortland street.

S. B. Morgan, General Manager.

Manufacturers of fire-proofing, fire-brick and Haverstraw brick and other structural material. The clay bank from which the product is manufactured is located along the Raritan river and about two hundred acres are under control of these works. The deposit, which consists of hollow brick and No. 2 fire-clay, has a depth of from eight to twenty-four feet and it is used principally in making fire-proofing material. The plant equipment consists of six boilers, of a total capacity of 600 horse-power, and engines of 400 horse-power. There are three pug-mills of 375 tons daily capacity. The kilns are down-draft and the nest of 36 have a capacity of 3,000 tons.

STANDARD TERRA-COTTA COMPANY.

Works at Perth Amboy and New York city. Office at No. 287 Fourth avenue.

A. Bullscheiwer, General Manager.

Manufacturers of ornamental terra-cotta, and the works were opened in 1891. The company is incorporated with a capital of \$100,000, and the plant is equipped with the following machinery: 100-horse-power boiler; 60-horse-power engine; two pug-mills, each of forty tons daily capacity.

The firm employs 135 men, most of whom are skilled laborers. The market is in New York, Boston and Philadelphia.

The supply of clay is purchased from the numerous clay-producers in the State.

STANDARD FIRE-PROOFING COMPANY.

J. A. Green, Superintendent.

Manufacturers of fire-proofing material, roofing-tile and flue-lining, wall-coping, sewer-pipe, underground electric conduits, fire-brick, hollow brick, ornamental and glazed brick, porcelain wash-tubs and sinks. The firm owns clay banks, one of which is located at the works and the other about one-half mile from the works. The clay banks at the works is about 200 feet wide and from 20 to 40 feet deep, of such quality as is suitable for making fire-proofing.

The second bank is from 15 to 20 feet deep, and the product is used in making flue-lining and conduits.

The company is also a large purchaser of fire-clays. The plant consists of three boilers of 150-horse-power each, two engines of 150-horse-power each, and these furnish power for operating five wet and dry pans, three pug mills, four sewer-pipe presses, tile and brick machines, two horse-power re-press and eight hand re-press machines. A force of four hundred men is employed in the several departments of the works.

RARITAN HOLLOW AND POROUS BRICK CO., KEASBY, N. J.

Edward Keasby, President; James C. Rossi, Superintendent.

The firm own their own clay-banks, one of which is close to works and the other at Bonhamtown. The clay deposit at the works has a light surface-covering of eighteen inches and the deposit is fifty-seven feet thick, which is made up of seven feet of fire-clay and the balance in hollow-brick clay. The Bonhamtown deposit is fire-clay of an average thickness of ten feet. The plant is equipped with the following machinery:

One 330-horse-power boiler capacity.

One 250-horse-power engine and one 125-horse-power.

Five 9-foot wet pans, each having a capacity of fifty tons daily.

Five Penfield brick and tile machines and a large number of hand re-presses.

Twenty-two down draught kilns fired by soft coal.

ADAM WEBER.

The plant is located at Weber, N. J., on the Raritan river, and the New York office at No. 633 east 15th street, and manufactures only fire clay product, making a specialty of gas retorts, shipping to Cuba, Mexico and South America, besides the domestic trade of our large Eastern cities.

OSTRANDER FIRE-BRICK COMPANY.

A. M. Horton, Superintendent at works; Main office No. 309 Second street, Troy, N. Y.

At one time this firm only mined fire-clay in New Jersey and manufactured it into fire-brick at Troy, N. Y. The plant on the Raritan river was built as an auxiliary to the main plant at Troy and it is now of quite extensive area and turns out only fire-clay products.

THEODORE SIMMONS.

Fire-Brick and Crucible Manufacturer.

The plant is located on the road from Perth Amboy to Metuchen, and consists of one eighty horse-power boiler and engine, which furnishes power for operating one pug-mill of twenty five tons daily capacity, one dry-pan of ten tons capacity, and one Tiffany brick machine having a capacity of eight to ten thousand per day. Two kilns, one a muffle of ten tons capacity and the other up-draught, round kiln of fifty tons capacity.

PERTH AMBOY TERRA-COTTA COMPANY.

New York city office, No. 160 Fifth avenue.

The works are located at Perth Amboy. The supply of clay is obtained from the company's clay-banks at Woodbridge, where they control 160 acres of clay-land, adjoining the Potter clay-banks.

The plant has four pug-mills of a total daily capacity of two hundred tons, and three wet-pans of about one hundred tons capacity. The manufactured product, which consists of ornamental architectural terra-cotta, is burned in thirty-two kilns, which are of various patterns.

THE TELLMIC MANUFACTURING COMPANY, CARTERET, N. J.

This plant, which manufactures vitrified electric conduits, has not been operated in the past year, and the property is now owned by Mr. Geo. W. Copeland, No. 44 Water street, New York city. The plant is to be put in operation in the spring.

The supply of clay used by these different manufacturing plants is obtained entirely from the Perth Amboy clay-beds, and in addition to the mining done by these several firms the following are engaged in the mining of clay and placing the same on the market.

DAVID A. BROWN, WOODBRIDGE,

controls a tract of 120 acres of fire-clay lands, which is located at Sand Hills, near the Lehigh Valley Railroad.

The deposit is covered with sand and gravel to a depth of ten feet, and the clay is from ten to thirty feet deep. It is sold for making fire-brick and saggars, and the product shipped via Lehigh Valley and Pennsylvania railroads.

DAVID A. FLOOD, WOODBRIDGE.

This has been a clay-producing property for the past sixty years, and is described in the Report on Clays, 1878. The banks now worked are on the south side of the road from Woodbridge to Metuchen and about one-half a mile from the former place. The bed is about sixty-three acres in extent and the stripping averages ten feet of sand, gravel and shale. The following is a section of the deposit as here exposed :

Red spotted fire-clay.....	4 feet.
Red spotted sagger-clay.....	3 "
White fire-sand.....	2-4 "
Fine moulding sand.....	4 "
Coarse pebbly fire-sand.....	8 "

and at this depth water is encountered. The product is shipped via Pennsylvania Railroad to Philadelphia; Wheeling, West Virginia; Canton, Ohio; and to the neighboring manufacturing firms at Perth Amboy.

D. P. DUNHAM, WOODBRIDGE.

Clay-bank located on the south side of the road leading from Woodbridge to New Brunswick. The deposit is from eighteen to

thirty-eight feet deep and includes all classes of clay, from terra-cotta to number one fire-clay. The stratum of fire clay is fifteen feet thick. Shipping facilities are by way of Pennsylvania Railroad.

JOSHUA LITTLE & SONS.

The clay-bank is about four acres in area and is located about two miles from Woodbridge, on the cross-road from New Brunswick to the Metuchen road. The stripping amounts to about eight feet, and the clay strata is from seven to ten feet. It is the ordinary terra cotta clay, and as the market for this class of clay is now very limited, the amount mined has not been very heavy.

GEORGE H. CUTTER.

This is a deposit of red terra-cotta clay adjoining the above property of Joshua Little, and is about five acres in extent, and the deposit is from fifteen to twenty-five feet thick, with a covering of sand and gravel of about ten feet. A small product has been mined, as the demand is so limited.

R. N. & H. VALENTINE, WOODBRIDGE.

The property upon which this firm mines is located at Sand Hills, near the Lehigh Valley R. R. siding, and they control over one hundred and fifty acres of fire-clay. Much of the fire-clay that was formerly unfit for use in the manufacture of fire-brick is now used in making fire-proofing products, but the principal product from this property is high-grade fire-clay, retort and sagger-clays. The fire-clay is about ten feet thick, being seldom less than six feet and often more than fifteen feet thick. The mining is carried on throughout the whole year, and shipping facilities are by way of Lehigh Valley and Pennsylvania railroads.

ALBERT MARTIN.

The bank is located in the Mutton Hollow district, at Woodbridge, and the deposit is owned by the Watson estate. The bank is from six to eight feet of fire-clay and about fifteen feet of hollow-brick clay. No mining has been done in the past two years, owing to the low prices prevailing in the clay market.

JOHN H. LEISEN.

The deposit worked by the above is located on the north side of the road leading from Woodbridge to New Brunswick, and contains about eight acres. In this bank there is a stratum of clay about thirty-five feet deep which overlies a bed of superior retort clay about ten feet deep. This bed produces a variety of different clays, as well as the high-grade fire-clays.

PATRICK L. RYAN.

Another bank located in the Mutton Hollow district and adjoining the previously described banks. The owner controls about sixty acres, and strips from ten to fifteen feet of dirt and inferior clay which lies upon a deposit of sewer-pipe and hollow-brick clay twenty feet thick, and this is underlain by pottery and fire-clay stratum about twelve feet thick. This bank produces some thirty-three different grades and qualities of clay, varying from the highest grade No. 1 fire-clay down to ordinary flower-pot clay.

B. DUNNIGAN.

This is a property owned by Henry Maurer, and located in the Mutton Hollow district. Mr. Dunnigan mines the clay at a certain sum per ton for the Maurer Works, and the whole product is used at this plant. The clay-bank contains twelve feet of hollow-brick clay and about twelve feet of fire and retort clay.

LEWIS C. POTTER, WOODBRIDGE.

This deposit adjoins Mr. Leison's banks and is about fifteen acres in extent. The stripping amounts to about ten feet of dirt which exposes a deposit of hollow-brick clay of about twenty feet in thickness overlying the fire-clay, which is six to twelve thick. Most of the product from this property is sold in Woodbridge, though some shipments have been made by rail and by water.

GEORGE W. RUDDY, WOODBRIDGE.

This property is located on the New Brunswick road, near Woodbridge, and adjoins the banks of W. H. Berry and the Salamander

Company. It has an area of ten acres. There is a deposit of fire-sand 20 feet thick, and underlying this is a variety of clays, varying in thickness from 15 to 17 feet. The owner controls another clay-bank on the road to Iselin, but the low price prevailing in the past few years has caused Mr. Ruddy to give up mining clay, and he has not been a producer for the past two years.

WILLIAM H. CUTTER.

The clay-bank is located about one-quarter mile west of road leading from Woodbridge to Perth Amboy, and has been producing clay for the past fifty years. The stripping amounts to about thirty feet, under which is red terra-cotta and inferior clays, resting upon four feet of hollow-brick clay, and this rests upon six feet of retort and fire-clay.

JAMES P. PRALL.

Clay bank adjoins that of W. H. Cutter, and the strata of clay are the same as above described. The inferior clays were formerly sold for making sewer-pipe, but the manufacture of this product is no longer carried on to any very great extent in this district; the market is gone, and the clays are consequently cast aside as of no value. The fire-clay is from 8 to 10 feet thick, and this is the product principally mined and put upon the market.

C. A. CAMPBELL.

The low prices of clay has closed this property, and no mining has been done during the past year. The deposit adjoins Mr. Ruddy's bank on the Iselin road, and about twenty acres have been opened. The bank is made up of from 10 to 12 feet of fire-clay, which is covered by about 14 feet of paving-brick clay.

THE HEIRS OF WM. H. BERRY, WOODBRIDGE.

Operated by Warren Drummond.

The clay-bank is located on the road from Woodbridge to Metuchen, and opposite the bank owned by David Flood. The clay, which averages 20 feet thick, is a superior retort fire-clay. A second bank located in the High Hill district is also owned by the above

heirs. The deposit consists of hollow brick, sewer-pipe, No. 1 and No. 2 fire-clay and other varieties of refractory clays. This bed is not now worked.

JOHN PFEIFFER, FORDS, N. J.

The clay-bed is located near Valentine station, in the Sand Hills district. The quality of the material consists of No. 1 and No. 2 fire-clay, sandy and red-spotted clays, and the total thickness of the deposit is from 18 to 20 feet, which has a covering of about 16 feet of sand and gravel. The owner has not produced any clay from this bed for some time, owing to the low prices now ranging in the market. He, however, works a clay-bank near Bonhamtown, on the Acken place, which is owned by Henry Maurer & Sons. The deposit covers eight acres, and the clay varies in depth from 10 to 16 and 18 to 20 feet. The product consists of several varieties of refractory material, all of which is used at the factory of Henry Maurer & Sons. About 1,000 tons per month is the product mined, and this requires the employment of from 18 to 20 men. A horse railroad one mile long connects the bank with the Raritan river docks, whence it goes by boat to Maurer.

WATSON FIRE-BRICK COMPANY.

U. B. Watson, President,

Perth Amboy, N. J.

Up to 1896 the above firm was engaged in manufacturing fire-brick, but for the past three years the company has only mined and sold the fire-clay from the clay-beds under their control. The clay-lands are located in Sand Hills district, between Valentine's and Ostrander Works. The firm controls 23 acres of different grades of quality. The stripping amounts to from four to six feet, and the monthly product amounts to about 1,000 tons, and from eight to ten men are employed in mining the product.

RARITAN RIVER CLAY COMPANY.

John C. Goodrich, President.

No. 113 East 20th street, New York.

This company controls 200 acres of clay-land, which lies between the Ostrander and A. Weber works. The deposit is refractory clay

of various qualities, and is found under a covering of from eight to ten feet of sand and dirt, and the clay extends to a depth of fifty feet. From eight to ten feet of the deposit is of superior fire-clay, used for the manufacture of high-grade refractory products.

WHITEHEAD BROTHERS' COMPANY.

No. 537 and 539 West 27th St., N. Y.

The firms own and operate a large number of clay and fire-sand deposits scattered throughout Middlesex county.

RARITAN RIDGE CLAY CO.

A. Campbell, President, Metuchen, N. J.

The firm is engaged in mining terra-cotta clay, and the beds of clay are between Metuchen and Perth Amboy.

In the South Amboy clay districts the following persons and firms are engaged in mining clays:

H. C. PERRINE & SON, SOUTH AMBOY.

This firm controls three deposits of clay, located in the vicinity of South Amboy, and the product consists principally of stoneware clay.

The first deposit is what is known as the Morgan bank, and is located on the line of the New York and Long Branch Railroad, near South Amboy. The tract contains thirty acres, and the deposit is covered with sand and gravel to a depth of thirty feet and under which there is a depth of clay of about thirty feet.

The second bed is at the head of the Cheesequake creek, and the depth is from eight to ten feet of clay. The third bed is located along the Camden and Amboy Railroad, about six miles from South Amboy and on the south side of the railroad. It is necessary to strip six feet to reach the clay, and the depth of the deposit is eight feet. The entire product is stoneware clay and is shipped to all parts of the Union and to Canada. The product mined amounts to about eighteen thousand tons per year, and from twenty-five to thirty men find employment in the several banks.

J. R. CROSSMAN, SOUTH AMBOY.

Mr. Crossman's clay-banks are a part of the Ridgeway tract, about four hundred and fifty acres in extent. The clay found upon the property is about one-half common red-brick clay and the other deposits of refractory clays of varying qualities, and having a depth of fifteen feet. Much of the product is washed and the impurities, principally sulphur-balls (pyrites), are thus removed. The product is used in the manufacture of patent plaster, asbestos boiler coverings and paper manufacture.

LEONARD FURMAN, SOUTH AMBOY.

Clay-bed is located on Cheesequake creek and the produce is stoneware clay and is found to a depth of from eight to sixteen feet. The stripping is rather heavy, varying from ten to sixty feet. The bed has not produced for the past two years, owing to the very low prices now ruling the market.

J. R. SUCH, SOUTH AMBOY.

The several clay deposits are of extended area and most of the product is high-grade washed clay for paper, pottery and refractory purposes.

CHAS. S. EDGAR, METUCHEN.

The clay-bank is on the road from South Amboy to South River, and the tract is about two hundred and twenty acres in extent. The covering is from three to twenty-five feet of sandy gravel and the deposit is from ten to twenty feet thick of fire-clay of the South Amboy bed. The ball clay is all washed, and about 90-horse-power boiler capacity is used in operating the washing-machines, and these have a capacity of 100 tons per week. Much of the product is sold to the Trenton potteries. About thirty men are employed all the year through.

A. O. ERNST, SOUTH AMBOY.

Owner and miner of about ten acres of clay-land, situated on the Cheesequake creek. The deposit lies from three to twenty feet below surface, and the excavating is carried on by open cut and shafts and

drifts. The deposit, which is stoneware clay, is 18 feet thick, and most of the product is shipped to Eastern ports, and almost the whole output is shipped by water.

CHARLES ROSE, SOUTH AMBOY.

The low prices for stoneware-clay has almost put an end to the product mined from this property, but a small output is still won from the clay-bed. The clay is mined by means of shafts and drifts. The deposit is from six to eight feet thick and is used for making stoneware.

J. B. ROBERTS, SOUTH AMBOY.

The clay-lands controlled amount to about one hundred and twenty-five acres, and are located along the south bank of the Raritan, and they are worked under lease from the owners, the Coleman heirs.

The bed of clay is from 10 to 20 feet thick, covered with a deposit of fine sand, usually from 12 to 18 feet deep. The product is refractory clay.

WILLIAM L. TAYLOR, RED BANK.

The property upon which mining is carried on is owned by J. L. Kearney, and the tract is seven hundred acres in extent. The product is South Amboy fire-clay.

MAC HOSE BROTHERS, PERTH AMBOY.

Miners of fire-clay from the Sand-hill district near Bonhamtown.

In addition to the clay-mining and the varied products of manufacture a very large amount of capital and extensive output of common building brick is produced in Middlesex county each year. The following plants have been producing during the past year.

SAYRE & FISHER, SAYREVILLE.

The plant at Sayreville is the largest in the State, and is thoroughly equipped with every type of the most improved brick-making machinery. The product consists of common building, pressed, front and enameled brick, fire-brick, and hollow brick for fire-proofing purposes.

EDWIN FURMAN COMPANY, SAYREVILLE, N. J.

This clay is a common brick material, located in the meadow through which the South river flows. The deposit is worked to a depth of from twenty to thirty feet, but from tests made in artesian well-borings the maximum depth of the bed is ninety feet. The plant, which has a capacity of 25 million, consists of 13 tempering wheels, 12 Adams brick machines, all of which are operated by steam-power furnished from one 100-horse-power boiler and one 40-horse-power engine. The product is burned in fifteen rectangular up-draught kilns, using hard coal fuel. The total kiln capacity is about nine million. Electricity is to be used in place of steam in operating the plant next season.

BOEHM & KOLEPH, SAYREVILLE, N. J.

The clay is about 30 feet deep and is on the large deposit of alluvial clay found along the South river. The plant, which is driven by steam-power, is made up of four tempering-wheels and an equal number of Adams machines. The kilns are ordinary stationary walled "Dutch-oven" pattern, using hard coal fuel. There are three of these kilns, having a total capacity of four hundred thousand, and the capacity of the plant is 8,000,000 per year.

THEODORE WILLETT, SOUTH RIVER, N. J.

This yard draws its supply of clay from the South river deposits, and it has been worked to a depth of 20 feet. There are three tempering-wheels and two Wildes brick machines, driven by steam-power. The kilns consist of four "Dutch-oven" pattern using hard coal, and the capacity is 80,000. The product is shipped by water, mostly to Newark, and the total capacity is 7,000,000 per year.

JAMES & MARIA BISSETT, SOUTH RIVER.

The clay deposit is forty feet of a strata of common clay. An artesian well sunk upon this property revealed a depth of clay for one hundred and ten feet. The plant is operated by one 60-horse-power boiler and engine and five tempering-wheels and three moulding machines, Adams pattern. The four kilns are square, ordinary

pattern, using hard coal fuel. The total capacity of the plant is 8,000,000, and it is all shipped by water to Newark, Elizabeth and Bayonne.

PETTIT & COMPANY, SOUTH RIVER, N. J.

The firm makes common building brick and mines sewer-pipe clay for the market. The brick plant is operated by one 150-horse-power engine, which drives five tempering-wheels and a like number of Adams moulding machines. The capacity is 9,000,000. The brick are burned in square, permanent walled kilns, using anthracite coal.

JOHN WHITEHEAD, SOUTH RIVER.

This yard is on the South River clay deposit and covers seventy-five acres. The clay is from thirty-five to forty feet deep and the product is used only in the manufacture of common brick. The plant is made up of one boiler of 100-horse-power and an engine of 85-horse-power which operates five tempering wheels and four Adams and four Sands brick machines. There are five kilns having a capacity—one of 500,000 and the other four about 400,000 each. These all use hard coal fuel. The capacity of the plant is over 10,000,000 per season and it is shipped principally to Newark, New York and Brooklyn.

GEORGE W. BENNER, METUCHEN.

Brick-yard and clay-bank are at South River, N. J., where he controls one hundred acres. The deposit consists of common and fire-clay. The total depth of the deposit is from 20 to 50 feet deep, and from 10 to 15 feet of depth is fire-clay. The plant is equipped with one boiler of 125-horse-power and an engine of 80-horse-power. There are four Adams brick-machines, having a capacity of 8,000,000 per year. The brick are burned in four "Dutch-oven" kilns, using hard coal for fuel.

YATES BROTHERS, SOUTH RIVER.

Manufacture common building-brick. The clay is on the South River deposit, and the depth to which work has been carried is 40 feet, and at this horizon water is met with, and consequently the mining is limited to this depth. The plant consists of 80-horse-power steam boiler and engine, with four tempering-wheels and four

Adams machines. There are four "Dutch-oven" kilns, using hard fuel, and they have a capacity of four hundred and fifty thousand. The capacity of the plant is 8,000,000, and the product is disposed of principally to Newark builders.

Along the Raritan bay, near Cliffwood, there is a large extent of clay suitable for manufacturing common brick, and the following firms have established manufacturing plants.

A. H. FURMAN, SOUTH AMBOY.

The brick-yard is located on Raritan bay, at the mouth of Whale creek, about four miles south of South Amboy. The tract comprises one hundred acres, and the clay is from 50 to 70 feet deep, and only common red brick is made from the product of the bank. The plant has two boilers of 125-horse-power each, and two engines which drive eight tempering-wheels and four "Wildes" brick-machines. Six square, walled kilns, using hard coal for fuel, are used in burning the product from this yard. The capacity of the plant is 14,000,000 per year. The owner also has a bank of fire-clay adjoining the property of Mr. Such, but owing to the demoralized condition of the clay market no mining has been done during the past three or four years. The deposit is 15 feet deep.

OLD BRIDGE ENAMEL CO. (BRICK AND TILE), OLD BRIDGE, N. J.

The product manufactured consists of enameled tile, terra vitrea and vitreous floor-tile. The company does not own any clay-banks and consequently buys from dealers. The ball-clay is obtained from South Amboy and the china clay is the imported product from England. The plant is equipped with one 50-horse-power boiler and one engine of 35-horse-power; one agitator of seven tons capacity, and six presses of a capacity of one ton each, besides a large number of hand-presses. There are three biscuit and two gloss kilns, having a total capacity of ten thousand square feet. The firm employ about fifty men.

SOUTH AMBOY POTTERY COMPANY.

H. C. Perrine, President.

This plant has been idle for the past three years, but preparations are being made to put it in operation again. The product manufactured consisted of Rockingham and yellow stoneware, and the kiln capacity is about 250 crates.

LOCKER, REGAN & COMPANY, SOUTH AMBOY.

Rockingham ware is made from the stoneware-clay, consuming about two hundred tons yearly. Steam-power is used and there are two up-draught kilns.

EDWARD FARRY, MATAWAN, N. J.

Brick-yard and clay-bank located on the side of the railroad track of the New York and Long Branch R. R. The deposit is 60 feet thick of common brick clay, but the working depth is 30 to 40 feet. The plant consists of six tempering-wheels and pits and four "Martin" brick machines. The burning is done in temporary arched kilns, using wood fuel. The machines are run by horse power. The clay is very stiff and requires a liberal addition of sand to make the clay workable. The capacity of the yard is 12,000,000 per year, and ninety men are employed.

THE NEW JERSEY TERRA-COTTA COMPANY, MATAWAN, N. J.

New York Office, No. 108 Fulton Street.

This firm now embraces the Matawan Terra-Cotta Company, and the plant is located at Matawan, N. J., E. V. Escheser, Secretary and Treasurer. Architectural terra-cotta is manufactured from New Jersey clays. The plant is equipped with engine and boiler power of 160 horse-power and these operate to two pug-mills of 20 tons capacity and two steam dryers. There are four "Muffle" up-draught kilns of a total capacity of 60 tons. From forty to forty-five men are employed, and the market is principally in New York city.

D. P. VAN DEVENTER, WELDON BUILDING, JERSEY CITY.

Brick-works at the clay deposit, close to Matawan creek. The clay is ordinary brick clay of a dark blue to black color, and is from 20 to 30 feet deep. The plant is made up of two tempering-wheels and two Martin machines. Burn in temporary arches using wood fuel.

DUNN, DUNLOP & COMPANY, MATAWAN.

The firm operates a pottery, making horse-shoe drain tile, preserve, snuff and butter stoneware jars. The plant is operated by steam-

power of 20-horse capacity, and runs two pug-mills and crushers, besides the turning machinery. There are two kilns of 10 and 20 tons capacity respectively. The clay-bank from which the tile is made is located on the Morristown road, about one-quarter of a mile from Matawan, and is blue in color and about 10 feet thick.

There is a covering of gravel from five to six feet thick which has to be stripped. The stoneware-clay is purchased from dealers.

NEW YORK AND NEW JERSEY FIRE-PROOFING CO.

The plant is an extensive one and the product consists of common building-brick and fire-proofing material. The clay is very stiff and makes a dense, hard brick, very impervious to moisture, and consequently well adapted for works under water. The capacity of the plant is one million common bricks per week.

CLIFFWOOD BRICK COMPANY, CLIFFWOOD, N. J.

The clay-bank, which comprises eighty acres, is located close to the brick-yard, on the line of the New York and Long Branch Railroad. The clay-bed is worked to a depth of thirty feet, but an artesian well was driven 155 feet in the strata, proving a great thickness of clay. The texture of the clay is very strong, and a large addition of sand is necessary to make good brick. The plant consists of three boilers of 300 horse-power, and three engines from 80 to 125-horse-power, and these drive seven tempering-wheels and a disintegrator, pug-mill and six Wildes Machines. There is a kiln capacity of 500,000 brick. They are the "Dutch-oven" type, using hard coal. The capital is \$100,000, and 225 men are employed. The capacity is 20,000,000 per year.

D. H. CLOSE.

Brick-yard adjoining Mr. Furman, near Cliffwood. The plant has been in operation during the past year, and manufactured hollow brick, fire-proofing and common brick.

ALEXANDER GASTON, CLIFFWOOD, N. J.

The clay area is about ninety acres and the depth to which the deposit is worked is 12 feet. \$20,000 is invested in the plant, which consist of

1 60-horse-power boiler ;
1 engine, 45-horse-power ;
6 tempering-wheels and two Martin brick-machines and one Philadelphia machine.

The bricks are burned in temporary arches, using wood fuel.

SILAS LEONARD, RAHWAY, N. J.

Operates the Rahway Pottery, and manufactures flower-pots principally, but makes some drain-tile. The deposit of clay is near Linden, and in quality is the common red clay, averaging two feet thick.

ROBERT RICHARDSON, NEW BRUNSWICK, N. J.

Manufacturers of glass melting-pots from imported German fire-clay. No domestic clay is used.

W. F. FISHER & Co., SOUTH RIVER.

The firm declined to give any information.

MONMOUTH COUNTY.

The three brick-yards reported last year comprise the whole clay industry of this county outside of the clay district, and during the past year the plants have been in operation. The firms manufacturing are as follows :

Drummond Bros., Asbury Park.
Samuel Brocklebank, Howell Post Office.
Edward Lippencott, Farmingdale.

The plant at Asbury Park has been improved during the year by the addition of a steam dryer, thus enabling the firm to operate and manufacture all the year through.

OCEAN COUNTY.

There are no brick-yards now in operation. The plant at Toms River, owned by Ayers Brothers, has been abandoned, and Mr. John C. Browne's yard at Lakewood has not produced for four years.

BURLINGTON COUNTY.

The brick and clay industry of this county is located along the western limit and in close proximity to the line of the Camden and Amboy Railroad, and in the neighboring territory of the city of Burlington. There have been no changes in the plants since last year, and the following firms have been making brick :

Sylvester Graham & Co., Bordentown, N. J.

John Braislin & Son, Crosswicks.

George E. Fell (formerly H. L. Newell), Florence.

Merrill Dobbins, Kinkora (city office, 24 South Seventh st., Philadelphia).

Burlington Architectural Terra Cotta Co., Burlington.

The Sanitary Enamel Clay Co., Burlington.

Firman Dubell, Mount Holly.

Mrs. Charles H. Hulmes, Mount Holly.

William Scattergood, Rancocas.

Henry C. Adams, Edgewater Park.

William E. Marter, Edgewater Park.

The McInnis Brick Company and Ellsworth Berryman have not produced during this year, and the latter plant is abandoned. In addition to the above industries there are two firms engaged in mining clay.

Alfred Platt, of Bridgeboro, is engaged in mining fire-clay and sand for the firm of J. W. Paxon, Pier No. 45, North Delaware avenue, Philadelphia. The clay-bank is along the Rancocas creek, and is about forty-five acres in extent. The upper stratum of clay is the red and red-spotted, averaging six to ten feet thick. The underlying stratum is three feet of white fire-clay, and under this is a deposit of fine white fire-sand, the depth of which has not been determined. Moulding-sand is mined along the Rancocas creek from Centreton to near Lumberton, and is found from one to three feet thick. A deposit of fire-sand is also worked on Burlington island, and the deposit, which underlays the whole island, is four feet deep.

A. A. ADAMS, WOODMANSIE.

Miner of fire and terra-cotta clays. The banks have been worked all the year.

CAMDEN COUNTY.

There are seven plants in this county and all, with one exception, are manufacturers of common building-brick. The following have been producing :

Augustus Reeves, Fish House Station.
Hatch Bros., Fish House Station.
Augustus Reeves, Maple Shades.
Budd Brothers, City Line Station.
James C. Dobbs, Collingswood.
Charles Hollowell, City Line Station.
Eastern Hydraulic Pressed Brick Co., Winslow Junction.
Golder & Riggins, Millville.

(Operating during the year on a deposit of clay at Moore's siding South Jersey railroad, one mile from Winslow Junction. The deposit is from 4 to 9 feet thick, and is used by Philadelphia firms in making pressed front brick. About 100 tons per day have been mined.)

ATLANTIC COUNTY.**INDUSTRIAL BRICK COMPANY, MAYS LANDING.**

The manufacture of pressed front brick has been carried forward through the year and the New Stone Brick Company has continued experiments in making brick under the Brice patents from sand. Satisfactory results are claimed for the process and under this method bricks are burned in from 10 to 20 hours, including the time taken in placing the brick in the kiln and withdrawing the same ready for shipment. Bricks have been made by this process from pure Jersey sand and from a mixture of sand and clay. The plant is still in an experimental stage, however. Other firms making common building brick are

Robert Muffet, Bakersville.
Julius Einsiedel, Egg Harbor City.

GLOUCESTER COUNTY.

The brick-yard of Charles B. Thackara, at Woodbury, is the only plant in this county which has been in operation. The yard of James C. Dobbs, about one-half mile east of Thackara's plant, has not been in operation for two or more years.

SALEM COUNTY.

There are three brick manufacturing plants in this county, located as follows :

David Haines, Yorktown.

Hiles Hilliard, Salem.

Smith B. Sickler, Salem.

The small yard at Fenwick is abandoned and no brick have been made in some years.

CUMBERLAND COUNTY.

The brick and clay industry of this county is confined to the manufacture of common building brick, excepting the plant of the Globe Fire-proofing Co., and Killborn & Dare.

The following firms have been manufacturing :

Benjamin Errickson, Bridgeton.

A. E. Bircham, Millville.

J. A. Hobart, Vineland.

The Globe Fire-proofing Co., South Vineland.

Kilborn & Dare, Rosenhayn.

The latter firm makes only pressed front brick and the plant equipment is the same as reported last year.

CAPE MAY COUNTY.

There is but one manufacturing plant of brick in this county.

Zolot Bros. & Co., Woodbine.

STATISTICS OF CLAYS, BRICK, TERRA-COTTA AND OTHER CLAY PRODUCTS FOR THE YEAR 1898.

1. COMMON BRICK—BUILDING BRICK—RED BRICK.

Number of men employed.....	3,252
Number of brick made.....	344,387,621
Value.....	\$1,578,983

2. FRONT BRICK—PRESSED BRICK.

Number of men employed.....	622
Number of brick made.....	35,983,000
Value.....	\$824,820

3. FIRE-BRICK, CRUCIBLES, RETORTS.

Number of men employed.....	512
Number of brick made.....	21,620,068
Value	\$461,127

4. PAVING AND VITRIFIED BRICK.

Number of men employed.....	.....
Number of brick made.....	200,000
Value.....	\$2,800

5. ENAMELED BRICK.

Number of men employed	150
Number of brick made.....	3,019,155
Value.....	\$215,171

6. ART AND ORNAMENTAL TILE.

Number of men employed.....	104
Value of product	\$132,000

7. TERRA-COTTA.

Number of men employed	373
Value of product.....	\$705,692

8. STRUCTURAL MATERIAL, FIRE-PROOFING AND HOLLOW BRICK, INCLUDING ROOFING-TILE.

Number of men employed.....	1,076
Value of product.....	\$857,994
Tons manufactured.....	196,485

9. MISCELLANEOUS MANUFACTURERS OF CLAY.

Value of product.....	\$233,914
Number of men employed.....	356

10. CLAYS DUG AND MINED, FIRE SAND, MOUNDING SAND, ETC.

Tons of clay and sand.....	687,679
Value.....	\$736,225
Number of men employed.....	1,105

GENERAL SUMMARY.

Total number of men employed.....	7,510
Total number of brick made	403 711,708
Total value of clay industry.....	\$5,748,726

II.

Report on the Iron Mining Industry.

BY GEORGE E. JENKINS, C. E.

Magnetic iron ore is mined in seven States of the Union, and in the volume of product New Jersey occupies third position, while in relation to the total production of all varieties of iron ores it is now ninth, where in former years it was seventh.

A review of the past forty years' mining, as shown in the State's annual product, reveals the fact that from 1855 to 1883 it was one of the most important industries in the State, and that during this period it was constantly growing in volume and value of product, yielding large returns on the capital invested as well as furnishing employment to a good-sized army of men.

The State's product reached high-water mark in 1882, which was due to a very great extent to the high value that iron ore had been commanding in the previous two years, when it sold at some of the mines for eight dollars per ton, and consequently stimulated mining to such a degree that every mineral deposit, however small, was made to yield and swell the increasing product. It was at this time also that many improvements were made in mining machinery, such as the introduction of better pumps and hoisting engines, and especially the advent of the air-power drill, together with the more general use of high explosives. This vigorous revival in business, after a long period of extreme depression, had the effect of a "boom," and the reaction which naturally followed affected the many mining enterprises, and the operators upon small and unfavorably located deposits as to shipping facilities, etc., were forced out of business, and the consequent shrinkage in product was quickly evident. Furthermore, the rich deposits of Hematite from the Northwestern States were reaching the Eastern market, and there was consequently a further reduction in prices. These consequent low prices have been the chief causes of crippling the New Jersey mines, although a number of the oldest and

deepest mines were closed because the deposits were exhausted and the prevailing margin of profit was so small that there was no inducement to spend any great amount of money in exploring for new deposits. In the past four or five years great improvements have been made in the shipping facilities from the Lake ports, and the consequent low freight rates have had the effect of forcing ore prices still lower, so that the average value of New Jersey ore during the past year was not more than two dollars per ton. When it is borne in mind that all of the mines now in operation are nearly or more than one thousand feet deep, involving heavy expenses in drainage and timbering, it is surprising that the enterprises have been able to live at all. It is certainly a compliment to the business ability and skill of the managers that the mines are working under so many disadvantages.

In the following review of the mines now in operation, the fact is very prominently brought out that the "economics of mining" is the foremost question before the managers. The evidence of this is seen in the continued adoption of every device and improvement in machinery and shaft equipment, whereby an increased output may be obtained at a reduced cost. All the mines reported last year have been in operation, but the Hurd mine at Hurdtown was closed in September, so that only about half a year's product has come from that source. The concentrating plant at Edison, however, began producing in October, and the two months' product from these works about made up the loss from the Hurd mine.

The following notes on the mines in operation during the year are appended :

Hurd Mine, Hurdtown, N. J.

The Hurd Mining Company, Benjamin Nicoll, President, operated this mine under lease from the year 1893 to October, 1898, when, owing to the exhausting of the ore body, the lease was surrendered. Mining during the past two years has been confined to removing the ore which had been left on the sides and in the roof of the old workings, and beginning at the bottom the "robbing" was carried upward to about seven hundred feet from surface, slope measurement. At this point work was stopped and the pillars of ore in the upper regions of the mine were not removed. During the past three months the owners have been making a series of explorations with the diamond-

drill in search of new shoots of ore. The first test was made at right-angles to the slope in the bed-rock of the old mine at six hundred feet from surface. The boring was made to a depth of one hundred feet and the core showed vein-material carrying seams of ore, but no deposit of any size was found. A second hole was started and reached a depth of fifty feet, when the operations were stopped by the water raising in the old working, drowning the parties out. Two bore-holes have been put down from surface southwest of the out-crop of the old shoot, and though one of these reached a depth of one hundred and seventy-two feet nothing very encouraging has as yet been developed. Other tests will be made for the purpose of making a thorough search for other shoots of ore.

From the present indications it looks as though another of New Jersey's oldest and best known mines was about to be added to the list of "abandoned mines."

At the time that work was stopped in the old slope it had reached a depth of six thousand feet on the slope and 2,600 feet vertical, being about 1,600 feet below tide-water and the deepest excavation in the State.

Richard Mines.

The large body of ore that was discovered in the foot-wall of this mine has been yielding large quantities of ore, and at no time in its history has the future of this mine looked more promising. During the year the drift in the foot-wall deposit has been continued westward, and these developments have proved the correctness of the conclusions in reference to the extent of this ore body, and as was premised in the report of 1896, the disturbance in the old vein, where the large "roll" in the foot-wall has taken place, marks the western limit of the deposit. The developments in this deposit have also been carried upward through an increased width of the vein, and a very large tonnage of ore has been blasted down. At six hundred feet, east of number two shaft, in the deepest workings of the mine, a drift has been driven eastward in a "pinch" of the vein, and as the work continued the vein was found to open out, and the vein, which has rolled out of its general course, is returning to the regular alignment of the dip of the deposit as the mining is continued. Work has progressed in the Mount Pleasant vein, and this deposit continues to be very much split up, and the ore is found in bunches of variable width and extent.

The "New Slope," which was started two years ago, is now down five hundred and nineteen feet, and cross cuts have been driven north and south. The one to the north is one hundred and twenty-six feet long, and at one hundred and fifteen feet a vein four feet thick has been cut. The southern cross-cut is one hundred and eight feet long, but no new veins have been cut and the face of the drift is still a considerable distance from the old working of the main vein.

The product for the year was the largest in the history of the mine, amounting to over 115,000 tons.

When all the improvements have been completed the output will no doubt be very much larger.

Edison.

The New Jersey and Pennsylvania Concentrating Company put their plant in operation about the middle of October and ran until the middle of December. The test was made on an ore carrying from ten to twelve per cent. of magnetite, and it is claimed that the results obtained were entirely satisfactory. About two hundred tons of bricks per day were manufactured on this trial and the product was used at the furnaces of the Crane Iron Works and the Thomas Iron Co. During the year 20,000 tons of sand, which is a by-product, was shipped to the Cement plants in Lehigh Valley. From two hundred and fifty to three hundred men are employed when the works are in full operation.

Lower Wood Mine, Hibernia, N. J.

There are now four stopes in this mine upon which mining has been done, and of these, 16, 18, 19 are on the Church Mine Property and number twenty stope is now the only one on the Lower Wood Lot. These stopes at the close of the year were not looking very promising, and from the very rocky character of the deposit it seems certain that the bottom of the paying deposit has been reached. The past year's product, however, has been a little smaller than the usual output. Some additional improvements have been made in the plant, particularly in the way of a new duplex Ingersoll air compressor, having a capacity of 1,900 cubic feet of free air per minute. Most of the ore mined in the past year has been obtained from the Church Mine, and in all probability the Lower Wood Workings will

be exhausted in the coming year. These are now at a depth of eight hundred and twenty feet vertical or nine hundred and five feet on the dip and about three hundred and thirty-five feet below sea level.

Wharton Mine.

The working area of mine is now comprised in ten available stopes, but only four are now yielding. Another sink eighty feet deep has been put down and at the bottom the vein is fifteen feet thick. These explorations show that there is a large body of ore in site, and with the two well equipped hoistways a large product can be mined.

The new shaft east of No. 3 was begun during the year, and at a depth of one hundred and five feet the vein was met. It is the purpose of the operator to continue this shaft till it intersects the drifts which are being driven eastward from the present workings in No. 3 shaft. The bottom sink is now 1,075 feet deep, being about two hundred feet below sea level. Improvements have been made to the mining plant in the way of an increase of 300-horse-power to boiler capacity and the installation of a new air compressor of a 2,500 cubic feet of free air per minute. The year's product has been the largest in the history of the mine, and it is used in the Wharton Furnace, at Port Oram.

The Hurd Mine and New Sterling Slope.

During the past year the cross-cuts on numbers 5 and 6 levels have been driven through the offset between the New Sterling slope and Hurd vein and the ore body on east side explored by back-stoping for over one hundred feet above the level of No. 5 drift. The ore body was from four to five feet wide and was followed till the width diminished to where it did not pay to continue mining.

The most eastwardly explorations are now two hundred feet from the offset. The company is now re-opening the old Hurd slope, and from a recent survey it is found that eighty feet of a sink will reach the vein, and if the ore body proves large enough drifts will be driven east and west so as to ultimately connect the workings of this year with the Hurd slope.

West of the offset in the old No. 13 shoot, the ore has practically all been removed, and the "back" in No. 4, as well as the stopes on Nos. 5, 6 and 7 levels, are very rocky and yield very little ore. The year's product has fallen off somewhat.

Beach Glen Mines.

After a period of idleness dating back to 1883, this property was re-opened in August by the Beach Glen Mining Company, and preparations are being made to do some mining.

The general run of the deposit yields a lean ore, but it is low enough in phosphorus to pass the Bessemer limit, and some very satisfactory results have been obtained from experiments in concentrating.

The mine is not deep and there is very little water to pump, and the ore ought to be mined cheaply and be able to meet the competition in the ore market, provided its richness can be brought up. No ore has, as yet, been shipped.

Franklin Zinc Mines.

Last year's report noted the consolidation of the zinc mining enterprises under the one management of the New Jersey Zinc Company. Operations have been alone confined to the deposit at Franklin Furnace, and both the North and South Mine Hill workings have been operated. A new concentrating plant of large capacity has been located near the mines, and the product from both openings is to be passed through this mill.

The smelting plants at Newark, Jersey City and South Bethlehem have all been in operation, and a new and extensive works is being built by this Company at Hazzard, Pa.

MINERAL STATISTICS

For the Year 1898.

Iron Ore.

The total production of the mines, as reported by the several mining companies, was 275,378 gross tons.

The total production, as gathered from the shipments of the railway companies, from mines in the State, and reported to the Geological Survey, amounted to 269,771 gross tons.

The increase, although small, is notable, the shipments increasing nearly thirteen per cent.

The table of statistics is reprinted with the addition of the amount for 1898:

IRON ORE.

1790.....	10,000 tons	.....	Morse's estimate.			
1830.....	20,000 tons	.....	Gordon's Gazetteer.			
1855.....	100,000 tons	.....	Dr. Kitchell's estimate.			
1860.....	164,900 tons	.....	U. S. census.			
1864.....	226,000 tons	.....	Annual Report State Geologist.			
1867.....	275,067 tons	.....	"	"	"
1870.....	362,636 tons	.....	U. S. census.			
1871.....	450,000 tons	.....	Annual Report State Geologist.			
1872.....	600,000 tons	.....	"	"	"
1873.....	665,000 tons	.....	"	"	"
1874.....	525,000 tons	.....	"	"	"
1875.....	390,000 tons	.....	"	"	"
1876.....	285,000 tons*	.....			
1877.....	315,000 tons*	.....			
1878.....	409,674 tons	.....	"	"	"
1879.....	488,028 tons	.....	"	"	"
1880.....	745,000 tons	.....	"	"	"
1881.....	737,052 tons	.....	"	"	"
1882.....	932,762 tons	.....	"	"	"
1883.....	521,416 tons	.....	"	"	"
1884.....	393,710 tons	.....	"	"	"
1885.....	330,000 tons	.....	"	"	"
1886.....	500,501 tons	.....	"	"	"
1887.....	547,889 tons	.....	"	"	"
1888.....	447,738 tons	.....	"	"	"
1889.....	482,169 tons	.....	"	"	"
1890.....	552,996 tons	.....	"	"	"

* From statistics collected later.

1891.....	551,358 tons	.....	Annual Report State Geologist.
1892.....	465,455 tons	.....	“ “ “
1893.....	356,150 tons	.....	“ “ “
1894.....	277,483 tons	.....	“ “ “
1895.....	282,433 tons	.....	“ “ “
1896.....	264,999 tons	.....	“ “ “
1897.....	257,235 tons	.....	“ “ “
1898.....	275,378 tons	.....	“ “ “

Zinc Ore.

The production of zinc ore in 1898 is indicated by the total shipments for the year; the total shipments, as reported by Mr. A. Heckscher, General Manager of the New Jersey Zinc Company, amounted to 99,419 tons.

The statistics for a period of years are reprinted from the last annual report :

ZINC ORE.

1868.....	25 000 tons*	.....	Annual Report State Geologist.
1871.....	22 000 tons	.....	“ “ “
1873.....	17 500 tons	.....	“ “ “
1874.....	13,500 tons	.....	“ “ “
1878.....	14,467 tons	.....	“ “ “
1879.....	21,937 tons	.....	“ “ “
1880.....	28 311 tons	.....	“ “ “
1881.....	49,178 tons	.....	“ “ “
1882.....	40,138 tons	.....	“ “ “
1883.....	56,085 tons	.....	“ “ “
1884.....	40,094 tons	.....	“ “ “
1885.....	38,526 tons	.....	“ “ “
1886.....	43,877 tons	.....	“ “ “
1887.....	50,220 tons	.....	“ “ “
1888.....	46,377 tons	.....	“ “ “
1889.....	56,154 tons	.....	“ “ “
1890.....	49,618 tons	.....	“ “ “
1891.....	76,032 tons	.....	“ “ “
1892.....	77,298 tons	.....	“ “ “
1893.....	55,852 tons	.....	“ “ “
1894.....	59,382 tons	.....	“ “ “
1895†			
1896.....	78,080 tons	.....	“ “ “
1897.....	76,973 tons	.....	“ “ “
1898.....	99,419 tons	.....	“ “ “

* Estimated for 1868 and 1871. Statistics for 1873 to 1890, inclusive, are for shipments by railway companies. The later reports are from the zinc-mining companies.

† No statistics were published in the Annual Report for 1895.

PUBLICATIONS.

The demand for the publications of the Survey is continuous and active, and several of the reports are out of stock. So far as possible, requests are granted by giving the reports to such requests.

It is the wish of the Board of Managers to complete, as far as possible, incomplete sets of the publications of the Survey, chiefly files of the Annual Reports in public libraries, and librarians are urged to correspond with the State Geologist concerning this matter.

By the act of 1864 the Board of Managers of the Survey is a board of publication, with power to issue and distribute the publications as they may be authorized. The Annual Reports of the State Geologist are printed by order of the Legislature as a part of the legislative documents. They are distributed largely by members of the two houses. Extra copies are supplied to the Board of Managers of the Geological Survey and the State Geologist, who distribute them to libraries and public institutions, and, as far as possible, to any who may be interested in the subjects of which they treat. Several of the reports are out of print, and can no longer be supplied by the office.

The first volume of the Final Report, published in 1888, was mostly distributed during the following year, and the demand for it has been far beyond the supply. The first and second parts of the second volume have also been distributed to the citizens and schools of the State, and to others interested in the particular subjects of which they treat. The third and fourth volumes are now being distributed from the office of the State Geologist.

The appended list makes brief mention of all the publications of the present Survey since its inception, in 1864, with a statement of editions that are now out of print. The publications of the Survey are distributed without further expense than that of transportation, excepting the maps, where a stated price covers the cost of paper and printing, as stated.

CATALOGUE OF PUBLICATIONS.

GEOLOGY OF NEW JERSEY, Newark, 1868. 8vo, xxiv + 899 pp. Out of print.
 PORTFOLIO OF MAPS accompanying the same, as follows:

1. Azoic and paleozoic formations, including the iron-ore and limestone districts; colored. Scale, 2 miles to an inch.
2. Triassic formation, including the red sandstone and trap rocks of Central New Jersey; colored. Scale, 2 miles to an inch.
3. Cretaceous formation, including the greensand marl beds; colored. Scale, 2 miles to an inch.
4. Tertiary and recent formations of Southern New Jersey; colored. Scale, 2 miles to an inch.
5. Map of a group of iron mines in Morris county; printed in two colors. Scale, 3 inches to 1 mile.
6. Map of the Ringwood iron mines; printed in two colors. Scale 8 inches to 1 mile.
7. Map of Oxford Furnace iron-ore veins; colored. Scale, 8 inches to 1 mile.
8. Map of the zinc mines, Sussex county; colored. Scale, 8 inches to 1 mile.

A few copies are undistributed.

REPORT ON THE CLAY DEPOSITS of Woodbridge, South Amboy and other places in New Jersey, together with their uses for fire-brick, pottery, &c. Trenton, 1873, 8vo., viii + 381 pp with map.

Out of print.

A PRELIMINARY CATALOGUE of the Flora of New Jersey, compiled by N. L. Britton, Ph.D. New Brunswick, 1881, 8vo., xi + 233 pp. Out of print

FINAL REPORT OF THE STATE GEOLOGIST. Vol. I. Topography. Magnetism. Climate. Trenton, 1888, 8vo., xi + 439 pp. Very scarce.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part I. Mineralogy. Botany. Trenton. 1889, 8 vo., x. + 642 pp.

FINAL REPORT OF THE STATE GEOLOGIST. Vol. II. Part II. Zoology. Trenton, 1890, 8vo., x + 824 pp.

REPORT ON WATER-SUPPLY. Vol. III. of the Final Report of the State Geologist. Trenton, 1894, 8vo., xvi + 352 and 96 pp.

REPORT ON THE PHYSICAL GEOGRAPHY of New Jersey. Vol. IV. of the Final Report of the State Geologist. Trenton, 1898, 8vo., xvi + 170 + 200.

BRACHIOPODA AND LAMELLIBRANCHIATA of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1886, quarto, pp. 338, plates, XXXV. and Map. (Paleontology, Vol. 1.)

GASTEROPODA AND CEPHALOPODA of the Raritan Clays and Greensand Marls of New Jersey. Trenton, 1892, quarto, pp. 402, plates L. (Paleontology, Vol. II.)

ATLAS OF NEW JERSEY. The complete work is made up of twenty sheets, each 27 by 37 inches, including margin, intended to fold once across, making the leaves of the Atlas $18\frac{1}{2}$ by 27 inches. The location and number of each map are given below. Those from 1 to 17 are on the scale of one mile to an inch.

- No. 1. *Kittatinny Valley and Mountain*, from Hope to the State line.
- No. 2. *Southwestern Highlands*, with the southwest part of Kittatinny valley.
- No. 3. *Central Highlands*, including all of Morris county west of Boonton, and Sussex south and east of Newton.
- No. 4. *Northeastern Highlands*, including the country lying between Deckertown, Dover, Paterson and Suffern.
- No. 5. *Vicinity of Flemington*, from Somerville and Princeton westward to the Delaware.
- No. 6. *The Valley of the Passaic*, with the country eastward to Newark and southward to the Raritan river.
- No. 7. *The Counties of Bergen, Hudson and Essex*, with parts of Passaic and Union.
- No. 8. *Vicinity of Trenton*, from New Brunswick to Bordentown.
- No. 9. *Monmouth Shore*, with the interior from Metuchen to Lakewood.
- No. 10. *Vicinity of Salem*, from Swedesboro and Bridgeton westward to the Delaware.
- No. 11. *Vicinity of Camden*, to Burlington, Winslow, Elmer, and Swedesboro.
- No. 12. *Vicinity of Mount Holly*, from Bordentown southward to Winslow and Woudmansie.
- No. 13. *Vicinity of Barnegat Bay*, with the greater part of Ocean county.
- No. 14. *Vicinity of Bridgeton*, from Allowaystown and Vineland southward to the Delaware bay shore.
- No. 15. *Southern Interior*, the country lying between Atco, Millville and Egg Harbor City.
- No. 16. *Egg Harbor and Vicinity*, including the Atlantic shore from Barnegat to Great Egg Harbor.
- No. 17. *Cape May*, with the country westward to Maurice river.
- No. 18. *New Jersey State Map*. Scale, 5 miles to an inch. Geographic.
- No. 19. *New Jersey Relief Map*. Scale, 5 miles to the inch. Hypsometric.
- No. 20. *New Jersey Geological Map*. Scale, 5 miles to the inch.

The maps comprising THE ATLAS OF NEW JERSEY are sold at the cost of paper and printing, for the uniform price of 25 cents per sheet, either singly or in lots. Payment, invariably in advance, should be made to Mr. Irving S. Upson, assistant in charge of office, New Brunswick, N. J., who will give all orders prompt attention.

ANNUAL REPORTS.

REPORT OF PROFESSOR GEORGE H. COOK upon the Geological Survey of New Jersey and its progress during the year 1863. Trenton, 1864, 8vo., 13 pp. Out of print.

THE ANNUAL REPORT of Prof. Geo. H. Cook, State Geologist, to His Excellency Joel Parker, President of the Board of Managers of the Geological Survey of New Jersey, for the year 1864. Trenton, 1865, 8vo., 24 pp. Out of print.

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ANNUAL REPORT of the State Geologist of New Jersey for 1883. Camden, 1883, 8vo., 188 pp. Scarce.

ANNUAL REPORT of the State Geologist of New Jersey for 1884. Trenton, 1884, 8vo., 168 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1885. Trenton, 1885, 8vo., 228 pp., with maps.

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ANNUAL REPORT of the State Geologist of New Jersey for 1892. Trenton, 1893, 8vo., x+368 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1893. Trenton, 1894, 8vo., x+452 pp., with maps.

ANNUAL REPORT of the State Geologist of New Jersey for 1894. Trenton, 1895, 8vo., x+304 pp., with geological map.

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ANNUAL REPORT of the State Geologist of New Jersey for 1896. Trenton, 1897, 8vo., xxviii+377 pp., with maps of Hackensack meadows.

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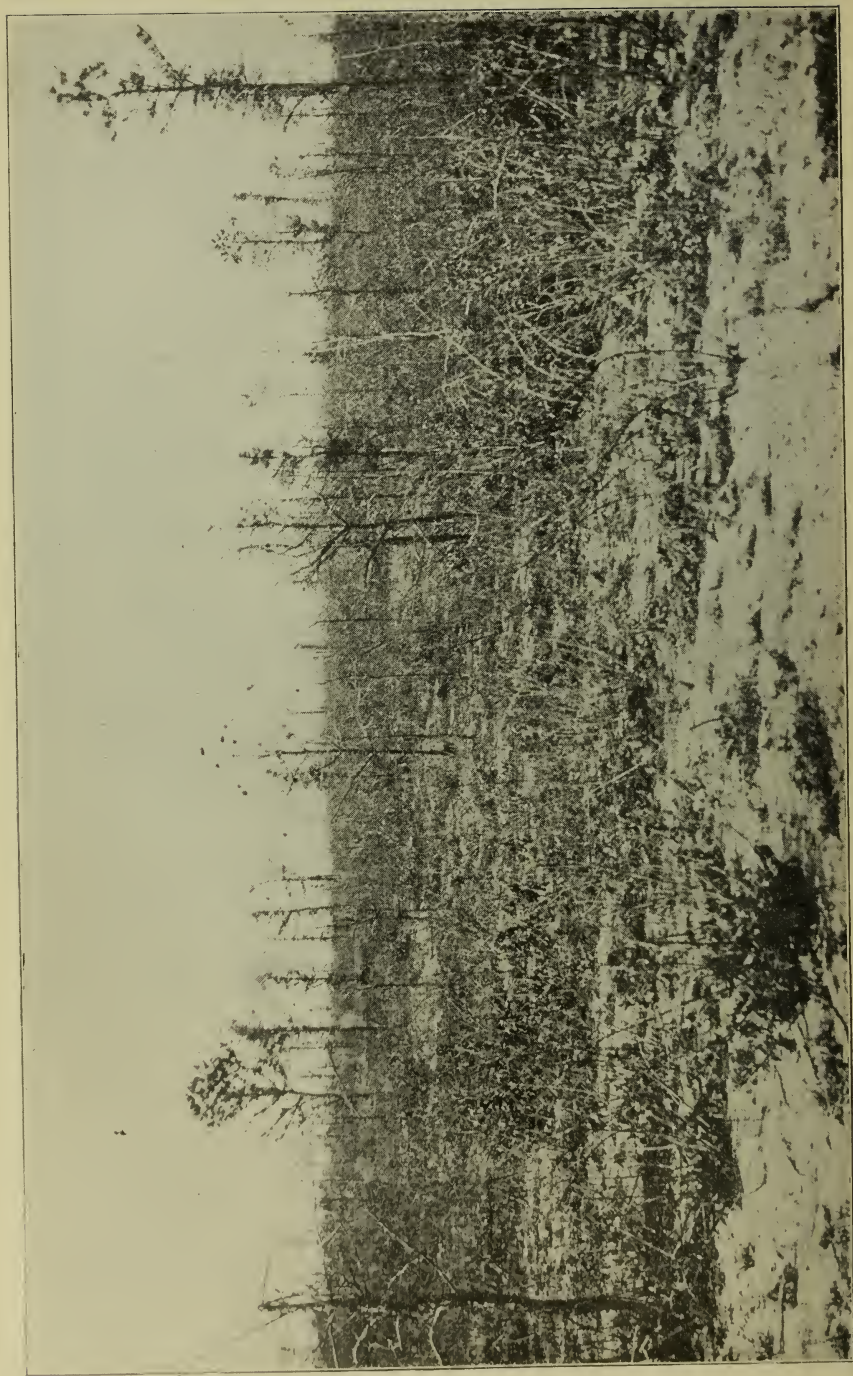


Plate I.—Typical Result of Forest Fires in South Jersey.

GEOLOGICAL SURVEY OF NEW JERSEY.

A STUDY OF
FOREST FIRES AND WOOD PRODUCTION

IN

Southern New Jersey

BY GIFFORD PINCHOT.

APPENDIX

TO ANNUAL REPORT OF THE STATE GEOLOGIST
FOR 1898.

TRENTON, N. J.:
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1899.

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INTRODUCTION.

The investigation whose results are here stated began in February, 1897. The field work in addition to that done by the writer was chiefly in charge of Henry S. Graves, assisted at times by E. M. Griffith and U. F. Bender. The calculation and statement of results was accomplished for the most part by Mr. Graves with the occasional help of Mr. Griffith.

The first object of this work was to show by actual measurements the loss to the State of New Jersey from forest fires. From the nature of the case it is almost impossible to show these losses in terms of dollars and cents, while they can be determined with considerable accuracy in terms of forest production. That is to say, knowing the capacity of the soil to produce valuable timber and the character of its present production, a consecutive and reliable description of the loss to the State becomes possible.

The second object of the work was to study the forest fires themselves, and, basing all recommendations on a fuller knowledge of their manner of burning, to devise better means of fighting them. While the investigation itself was confined for the most part to South Jersey, the plan for protection against fire is applicable to the whole State.

Forest fires, it is well known, are particularly dangerous in New Jersey to the south and east of a line drawn from Long Branch, in the northeast, to Salem, in the southwest. Various statements of the damage they occasion have been made from time to time, but the close study of the fires seems to have been almost entirely neglected. It may be added that the total effect of fire on the forests of South Jersey, according to actual measurements taken in the field during the present investigation, is to substitute a few cords of very inferior fuel per acre for a mature yield of from five to ten thousand board feet of valuable timber.

The plates in this paper are from photographs owned by the author. Many of them were taken to illustrate a handbook of forestry shortly to be issued by the Division of Forestry, U. S. Department of Agriculture.

I.

FOREST FIRES.

On account of the flatness of southern New Jersey the forest fires are not much affected by topography, but are governed chiefly by the wind and by the amount of combustible material. The soil is influential in that it is deep, dry, porous sand. It does not hold moisture well, especially after the humus has been destroyed, and the new, upper layer of vegetable matter quickly becomes dry, affording abundant material for the fire. When there is a thick layer of humus, a light surface-fire will merely run over the top of the ground, burning the upper layer of leaves, twigs, etc., which, as yet only partially decomposed, are loose and dry. Repeated fires, or very severe fires, destroy the humus down to the mineral soil. The most rapid and dangerous of all fires are those which burn in the tops of the trees. No ground-fires are so swift in old timber, and none do such certain damage. On account of the wonderful fire resistance of the Pitch Pine, very few surface-fires in South Jersey are followed by the death of the larger trees of this species. Those which burn in peaty ground naturally kill everything they reach by burning or charring the roots, but such fires are usually of very limited extent.

When a fire first starts it eats slowly out on all sides in a gradually increasing circle. When it becomes large enough for the wind to catch it, a head (a name for the fiercest and most rapid part of a fire, used here for want of a better) is formed, at first narrow, but widening as it is driven on before the wind, until finally it may be several hundred feet or even rods in width. A single fire would burn off a plot shaped somewhat like a wedge or a cigar. The sides or wings eat out slowly against the wind, seeming almost to be dragged along by the main head of the fire. Before the main head are small independent fires set by flying sparks, which are often carried for one-half mile or more by strong winds. Pine bark detached from the tree carries fire to the greatest distance. These small fires are most noticeable when

the main fire is not traveling very fast, because there is time for them to make some headway before the latter reaches them. Such independent fires are characteristic of the wings as well as of the head, but in that case are nearer the main line of fire. The wings burn in an a narrow band of flame, gradually eating out diagonally in an irregular line. The flames are fanned backward and forward under the influence of the wind and the air currents caused by the main fire and the hotter parts of the side-fires.

A back-fire, running against the wind, acts in the same way as the side-fires, except that the latter burn obliquely with the wind, and the back-fire directly against it. There is always danger of setting an independent fire when the back-fire is first started. As the main and back-fires approach, the latter, under the suction of the front, rushes toward it, burning the intervening ground almost instantly. Living leaves seem to wither before they are touched by fire, under the influence of the great heat.

With shifting winds the head of a fire swings back and forth, burning an irregular line. With a sudden change of wind the long wing may become the head, and then a much broader, more fearful fire results. The wings often burn to a road and cross by jumping or by creeping over dried leaves, or sometimes gain such headway in good burning that a new head and practically a new fire is set going. Often when the head has been checked the wings form new heads and there are two or more fires to fight instead of one. If the wings burns to a swamp, the fire is deadened and smoulders in the damp moss and duff. Now and again it reaches a dry spot, blazes up, and rushes into the crowns with a crackle and a roar, and a dense cloud of black smoke.

Fires usually slacken at night on account of the cessation of the wind and often because the air becomes damp and the dew falls heavily. Frequently, in looking over burned areas, one sees narrow belts of dead timber, as if the fire had burned in strips. Sometimes this is the result of a slight change in the surface of the ground, or is caused by a road, by the formation of separate heads starting from the wings, by the temporary checking of the fire by poor burning, or by the deadening of the fire at night.

PRESENT METHODS OF FIGHTING FIRES.

It is customary in South Jersey to check severe fires by back-firing, and to extinguish ground-fires by throwing sand on the flames or by

beating them with green boughs or with shovels. There is nothing more effective in extinguishing fires than sand, and, fortunately, the character of the soil makes it possible to obtain this material in abundance. It is astonishing how long a line of fire can be put out by one shovelful of sand thrown by a skillful man. When the fire burns in the crowns of the trees back-firing is the only method of checking it. It is customary to start the back-fire along the windward edge of a road, taking care to put out all sparks which are carried across it. As soon as the head is stopped the wings are extinguished as rapidly as possible with sand, and if a new head is started it is checked by back-firing.

With an experienced leader and a corps of expert fire-fighters even severe fires can usually be completely extinguished in a few hours. The difficulty often is that the fires are not attacked until they reach dangerous proportions, and then, when work is finally begun, the efforts of the men, although they may be skillful fighters, are often wasted through the lack of leadership and organization. It frequently happens that after the main fire has been checked the men stand about and discuss where the next point of attack shall be, and meanwhile a new head has been formed, and all the work has to be done again.

Another conspicuous fault in the present methods is that the fires are so often left without further watching when apparently extinguished. A careful patrol is essential for a considerable length of time after a fire is apparently out. All smouldering stumps, logs, cones, etc., should be completely put out with sand, and the ground should not be left until it is positively certain that no trace of the fire remains. Fires are sometimes left to burn unchecked when it is known that there is a Cedar swamp or a stretch of bare land before them. Fighters often leave the fire when it dies down at night, because they are tired and know that it will burn but slowly until sunrise. In the morning the fire breaks into new vigor, and the work of the day before is lost. With an organized force and a competent leader such mistakes would not happen, nor would the dangerous practice of indiscriminate back-firing be allowed to continue.

BETTER METHODS OF FIGHTING FIRE.

Plans for protection against fire have been, for the most part, based on the Minnesota and Maine laws. These laws are excellent for the

conditions existing in those States, but they would not prove efficient in South Jersey. A plan to make the town officers fire-wardens might be effective in the farming and mountainous sections of the State, but for the Pine belt an additional service is essential to organize the fighting force, to locate the fire instantly, and to begin the attack promptly on every fire that starts. A leader is required, cool, intelligent, and quick to act, thoroughly familiar with all roads and paths, and who can decide at a glance the best point of attack. With town officers as fire-wardens it would take longer to locate the fires, there would be less prompt action in reaching them, and the actual fighting force would be less efficient.

The State of New Jersey may be divided into two sections, with regard to the prevalence and effects of forest fires, by a line running from Long Branch to Salem. To the north and west of this line these fires, while exceedingly destructive, are less formidable than in the eastern and southern portions of the State. In North Jersey the effect of fire in the woods is not, as a rule, to render the forest soil wholly unproductive, but only to reduce the character and diminish the value of its products. The loss from this source is very great, yet it is much less complete and appalling than in the flatter, sandy portions of the State.

In South Jersey the effect of forest fires is best illustrated by the plains of Ocean and Burlington counties. Here a succession of such fires has so far reduced the fertility of the soil that it is capable of producing, for the time being, nothing but stunted Pine sprouts of no value whatever. The condition of the Plains is due wholly to fire. The adjacent regions are rapidly assuming the same character under the influence of repeated burning, and the complete impoverishment of southern New Jersey is close at hand unless the fires can be stopped.

Such facts and figures as are contained in the present report may be made to contribute in many ways to the safety and protection of the forests; but investigations and reports must alike fail of their object if they do not secure the inauguration of active measures against forest fires on the part of the State. That these fires are enormously destructive is already well known. That it is practicable to prevent them is proved beyond question by these investigations, and by the success which has elsewhere followed efforts to that end in the face of difficulties not less great.



Plate II.—Badly Burned Pine Land. Pines Killed Outright, Oaks Sprouting from the Stump. Soil Pure White Sand, Resembling Snow in the Picture.
Near Tuckerton, N. J.

The proposed forest service described below is intended to attack this evil in two ways: First, by disseminating forest information throughout the State; and second, by providing efficient means by which fires can be reached in their early stages and measures can be taken against them without loss of time. The details of the plan have been worked out with special reference to South Jersey, but the general scheme is applicable, with a few changes to meet local needs, to the whole area of the State.

Like the question of slavery, the question of forest fires may be shelved for a time, at enormous cost in the end, but sooner or later it must be met. Every consideration of prudence and economy is on the side of prompt and thoroughgoing action.

With suitable local modifications, this system of forest protection may be applied to all forest lands throughout the State. But since the cost of establishing it at once throughout the whole State would be very large, it is recommended that efforts be directed in the beginning chiefly, but not exclusively, to those parts where the loss from forest fires is most severe.

The portion of New Jersey within which fires have been and are still most frequent and destructive comprises the southern border of Monmouth county, Ocean county, the eastern and central portion of Burlington county, the eastern part of Camden and Gloucester counties, and the larger part of Cumberland, Cape May and Atlantic counties. The State Forest Service here proposed is intended at first to devote almost its entire energies to this area during the season when fires prevail. During the remainder of the year it is capable, if a trained forester be selected as its executive head, of disseminating right ideas and methods of forestry and fire-protection widely through the State. In a word, the object in view is not merely to prevent fires now, but to awaken such a conception of the usefulness of forests, and impart such a knowledge of right ways of handling and protecting them, that the hearty co-operation of the people, both in the counties named above and throughout the State, will be secured. The safety of the forests of any region must ultimately depend upon local sentiment regarding them, and no attempt to protect them which disregards this fact can succeed in the long run.

The wide distribution of printed information regarding forest fires, and the best means of extinguishing them, should be a duty of the Forest Service, and it should post in conspicuous places, throughout the area where fires are numerous, fire notices printed on cloth and

protected by wire netting. These notices, in addition to a brief statement of the law and the penalties for its violation, should give succinct directions for action in case of fire, together with the names and places of residence of the nearest Forester, Fire Warden, and Fire Commissioners.

ORGANIZATION.

Successful organization against fire should aim to attain three things:

1. The rapid and accurate location of the fire.

Great practical difficulty has been found in ascertaining the exact location of a fire, although smoke may be plainly visible and apparently at no great distance. Even men thoroughly familiar with a region find it extremely difficult to determine the actual distance of a fire in miles, since its apparent distance is largely influenced by the direction of the wind, the state of the atmosphere, and the size of the fire.

2. The speedy arrival of the fighters at the scene of a fire.

In forest fires, as in those against which the fire departments of our cities are organized, time is of the first importance. Time saved in reaching the scene of a fire may result in money saved to the extent of hundreds or even thousands of dollars in damage done and in the cost of fighting. Some of the most destructive forest fires in the past could have been easily extinguished had prompt action been taken while they were young. The Hinckley fire in Minnesota was a case in point.

3. Vigorous and intelligent action on the part of the fighters.

Nothing is commoner at the scene of a forest fire than to find the efforts of the fighters nullified, or even made positively dangerous, on account of bad judgment, lack of discipline and the scattering of efforts. The danger of many fires is increased by the injudicious setting of back-fires by men whose judgment is warped by excitement, or who have become panic-stricken by the fear of harm to themselves or to their property.

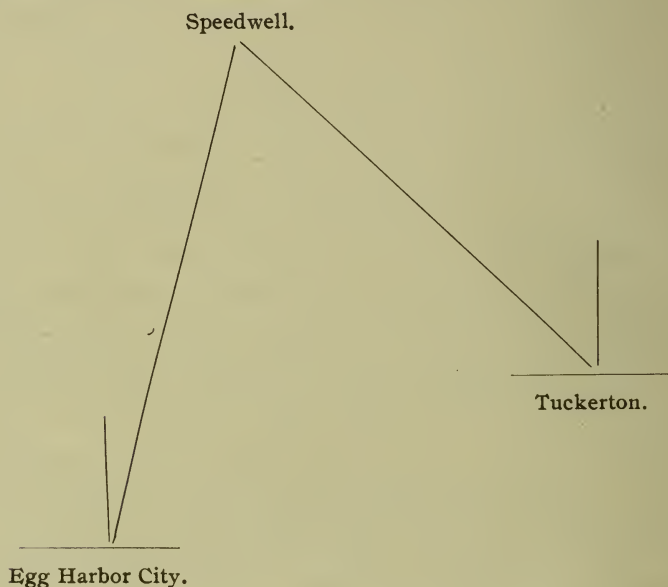
The plan here proposed contemplates an annual expenditure of \$10,300. The cost of equipment is estimated at \$2,650, and the total for the first year is thus \$12,950. The area to be protected is,

roughly, 1,400,000 acres, and it is believed that an expenditure of but little more than half a cent per acre per annum is not excessive. The organization recommended is as follows:

1. *A Forester*, whose duties would be to act as executive officer of the Forest Service; to repair at once to all fires, and when there take entire charge and direction of the efforts to extinguish them; in extreme cases to employ assistants outside of the service to that end, but only to the limit of the appropriation for that purpose; to keep constantly and accurately informed upon the condition of his charge; to make frequent tours of inspection; to issue permits for burning brush, grass, swamps or meadows; to keep a descriptive record of all fires; to arrest any violators of the forest laws, and, in general, to co-operate with local residents in the attempt to protect their property against fire. The Forester should have headquarters at Winslow, from which point all parts of his charge could be easily reached by rail. A very considerable portion of his time should be occupied in a personal inspection of the forests under his care, and he should be thoroughly familiar with them and with all their topographical features. Whenever unoccupied by his duties in relation to fires, the Forester should give advice and instruction, free of charge, to residents of the State, upon all matters relating to the protection, care, and management of woodlands, both by letter and by personal conference and visits to forest areas.

2. *Four Assistant Foresters*. Each Assistant Forester should be in charge of a fire station at one of the following points: Whittings, Tuckerton, Egg Harbor City and Millville. Each station should be located on top of the highest building available for that purpose, and within easy reach of a telegraph office. Where a location of this kind is not available, it will be necessary to construct a scaffolding high enough to afford a view over the surrounding timber, and large enough to carry a small room for shelter at the top. Each station should be equipped with a graduated brass circle, surmounted by a small telescope. As soon as a fire is discovered, the Assistant Forester should train his telescope upon it, read its direction upon the graduated circle, and telegraph the same to his chief and to the other stations from which the fire may be seen. The reading of the angle of a fire from any two stations, when laid down on the map with a protractor and rule, will give the exact location of a fire at once. (See the accompanying diagram.) Each station should also be provided

with a horse and wagon, for the purpose of conveying the Assistant Forester and any assistants to the scene of a fire without unnecessary delay, and shovels, lanterns, and canvas water-buckets should also be supplied.



EXAMPLE.—A fire breaks out. Tuckerton telegraphs Egg Harbor City that the fire bears directly northwest. The latter replies that the direction from that station is north 21 degrees east. The Assistant Forester at each station at once plots these courses on his map, and each finds that the fire is at Speedwell. The Forester, meantime, has discovered the location of the fire by the same process, the bearings having been wired him at once. He sends his orders by wire without delay, and proceeds himself to Harris station, on the New Jersey Southern Railroad, by the first train. In less than an hour the whole force of the Forest Service within reach of Speedwell may be concentrating to check the fire.

The duties of an Assistant Forester should be to repair at once to all fires within the limits assigned to him, and when there to take entire charge and direction of the efforts to extinguish them until the arrival of the Forester, who should be notified at once by telegraph on the outbreak of the fire. During the season when fires are dan-



Plate III.—A Fire Checked by a Road and by a Narrow Path Shown in the Foreground. Second-Growth Pine. Burlington County, N. J.

gerous, each Assistant Forester should be required to be on watch from his tower during the hours of daylight. During the rest of the year he should advise and assist local residents in the construction of fire-paths, in planting valuable species of trees, and in taking proper care of existing forests, under the direction of his chief. He should familiarize himself to the utmost with every road and path, however little traveled, and with all water-courses throughout his charge, and should report all violations of the law to his superior. His presence should be required at the burning of brush, grass, meadows, and swamps, except in cases where danger of the spread of fire is very slight; and he should see to the enforcement of the forest-fire laws and the performance of their duties by the Fire Wardens.

3. *One Hundred Wardens.* Each of these men, in consideration of the annual payment of \$25, should bind himself to repair at once to every fire occurring within the limits assigned to him (and these limits should overlap so as to insure the attendance of several men at each fire), to do his best to extinguish it, and, in the absence of his superiors, to take entire charge and direction of the efforts against it. He should report all infractions of the forest-fire laws to the Forester.

The advantage of the appointment of Wardens is that it secures a much larger number of men than could otherwise be obtained to fight fires in their early stages, and creates a class with a direct personal interest in not having fires occur. The salary of a Warden should be paid whether fires take place within his limits during the year or not, because the service to the State will be greater in the latter case than in the former. It is immensely cheaper and better to prevent fires from occurring than to extinguish them after they have begun. The fewer fires within the limits of a Warden the easier it would be for him to earn his pay.

4. *Township and County Officers.* Township and county officers should, *ex-officio*, be given the title of Fire Commissioners, and should be required to repair at once to every fire within the limits assigned to them, to do their best to extinguish it, and to take charge of the efforts to that end in the absence of Foresters or Wardens. Failure on the part of a town or county officer to fulfill his duty in this respect should make him liable to a fine, to be collected through the application of the Forester.

5. *Extraordinary Assistants.* All Foresters, Fire Wardens, and Fire Commissioners should have the power to requisition the services of any citizen for the purpose of extinguishing a fire, and failure

to respond should be punished by a fine of \$5 for each offence. The Forester should be empowered to pay for such service at a fixed rate in each county. Great care must, however, be exercised in this matter, because, while great fires cannot be successfully attacked except with a large force, the temptation to burn woods as a means of getting work is strong among men of a certain cast of mind.

6. *Fire-Paths.* The construction of fire-paths would be exceedingly costly; fortunately it appears to be unnecessary. Throughout Southern Jersey in addition to the main thoroughfares there are great numbers of wood-roads now largely disused. These roads would serve admirably as fire-paths if they could be cleared of inflammable material. For this purpose I recommend that two machines be constructed, similar to the revolving-brush sweeping machines used in large cities, but of such a size that the wheels will track in the country roads, while the brush will occupy the space between the ruts. Such a machine with one horse and one man will clear as many miles of road as the horse can traverse on a walk in a day. It is believed that fifteen miles may be easily accomplished. Two of these machines operated during the autumn after most of the leaves have fallen, and again in the spring after the oak leaves have become detached from the trees, would, it is believed, clear valuable fire-paths impassable by a moderate ground fire, and indispensable in more vigorous conflagration as lines of defence throughout the greater portion of the region where forest fires are especially to be feared.

COMMUNICATION.

It is of the first importance that the Forester should be in easy and rapid communication with each of his four immediate subordinates, and each of the latter with the others. This is an essential of the plan proposed. It is evident that a telephone line, connecting the stations with each other and with the Forester, at Winslow, would be the most satisfactory means of accomplishing this end, but the cost of such a line would be heavy, and it has not been deemed wise to suggest its construction at once. For the present, the location of fire stations within easy reach of existing telegraph lines will suffice.



Plate IV.—White Cedar Killed by Fire, Marigold Swamp, near New Gretna, N. J.

II.

THE EFFECTS OF FIRE.

The harm that forest fires do may be classified as follows: 1st, damage to the standing timber; 2d, destruction of young growth; 3d, destruction of the forest floor; 4th, depreciation in the value of forest property; 5th, encouragement of theft and disregard of the rights of property, and discouragement of thrift and foresight among the people where fires occur; 6th, general impoverishment and degeneration of the regions where they are common.

DAMAGE TO STANDING TREES.

The damage to the standing timber is dependent on the kinds of trees in the forest, on the character of the latter, and on the time of the year when the fire burns. Young hardwoods suffer severely, but are often comparatively prompt in recovery. Pine forest is the prevailing type in South Jersey, and its relation to forest fires is of special interest. One of the distinguishing characteristics of the Pitch Pine is its ability to resist fire and to recover after severe injury. The Shortleaf Pine is also able to withstand severe fires, but its recuperative capacity is much less than that of the Pitch Pine. In each case the trunk is covered with a thick, corky bark, which is often burned till it is charred without apparent injury to the living parts of the tree. The outer bark scales off after a time, and the signs of fire disappear, except near the ground. In old Pine forests a light surface fire usually does but little damage to the standing timber. Sometimes, however, if the forest is dense and there is a heavy matting of litter on the ground, the fire burns so fiercely that the trunks of the trees are seriously damaged, and in the case of small timber, the trees may be killed. The same is true where the ground is covered with underbrush, which becomes dry and burns with intense heat. If the fire runs over the ground in spring before the sap begins to move, the

damage is much less than after the season of vegetation has begun. Decay frequently creeps in at the butt of severely burned timber.

EFFECT ON CEDAR SWAMPS.

White Cedar is extremely sensitive to fire and is easily killed, especially if the crown is affected. As a rule, however, Cedar swamps will not burn except in the early summer when it is very dry, and often they will not burn even then. Wet swamps burn only in extraordinarily dry years, or when an unusually hot fire is driven through the trees by a strong wind. The trees on the edges of swamps, however, are frequently killed before the fire is stopped by the damp sphagnum moss. Sometimes the larger trees are not killed outright, but die gradually, beginning in the tops.

INJURY TO YOUNG GROWTH.

The larger hardwood trees resist fires admirably, and are killed only in the case of very severe fires. Young growth is often killed outright. All young trees are more sensitive to fire than larger ones, because the bark is thin and delicate, and also because the branches being low what is a surface fire is to them a crown-fire, killing their tender shoots. Young Pitch Pine, however, withstands remarkably severe burning. Frequently surface fires burn up to the crowns of small Pitch Pine, scorching the lower branches, but leaving most of the crown intact, and with it the life of the tree.

INJURY TO THE SOIL.

One injurious effect of forest fires which is apt to be neglected or even disputed is that which results from the destruction of the layer of vegetable waste and mold which is always found on the ground in undisturbed forests. This forest floor, as it is called, is made up of two parts: 1st, the upper wholly or partially decayed mass of leaves, twigs, and other vegetable material, called litter; and 2d, the thick, brownish, crumbly mass of real humus, which finally is intimately mixed with the mineral soil. In New Jersey the upper layer of litter, which becomes exceedingly dry and burns rapidly, is generally looked upon as a positive evil, a danger to the welfare of the forest. This

has led many owners of forest property to burn their land every spring before the dry season commences, and thus destroy the litter. Fires are in this way prevented from burning over the land later in the season and injuring the timber. Many people believe that this is the only way to protect their land from fire. As long as there is no organized fire service, this annual burning of the land and the consequent deterioration of the forest is certainly better than the destruction of valuable timber. If, however, the danger from forest fires can be reduced, which is shown elsewhere to be entirely possible, this annual burning becomes unnecessary. That it should cease is extremely desirable in view of the fact that in the majority of cases it is an actual injury to the forest.

An occasional light surface-fire can do comparatively little harm to the forest aside from the injury to young growth, for only the upper layer of dried leaves is burned and the lower more valuable humus remains. Severe fires destroy the whole of the forest floor, and a considerable number of years must pass before it can be formed again. Continual burning, if it does not actually destroy the layer of humus, prevents new humus from forming, and what is left finally becomes disintegrated, and the same result follows as though it were destroyed at once. Whatever may be said of individual fires, their effect as a whole in South Jersey is simply disastrous.

On the loose, porous, sandy soil of southern New Jersey whatever tends to prevent the drying-out of the surface is valuable, for without moisture in the soil all other factors are of little consequence. According to German authorities, humus formed under conifers is capable of holding four or five times its own weight of water without losing a single drop, and it has beside a remarkable power of absorbing watery vapor from the air. A layer of humus is a powerful factor in preventing evaporation, and in New Jersey this drying-out of the soil is one of the most serious effects of the removing of the forest cover. Prof. Ebermayer, of the University of Munich, has established by actual experiments that a forest soil with a good layer of humus will lose two and one-half times less water by evaporation than forest soil where the humus is wanting.

Humus, by mingling intimately with the mineral soil, adds to it a proper consistency; it makes binding soils more porous, and loose soils more tenacious. It moderates the extremes of temperature in the soil, and this is of great importance in sandy regions. Not only does

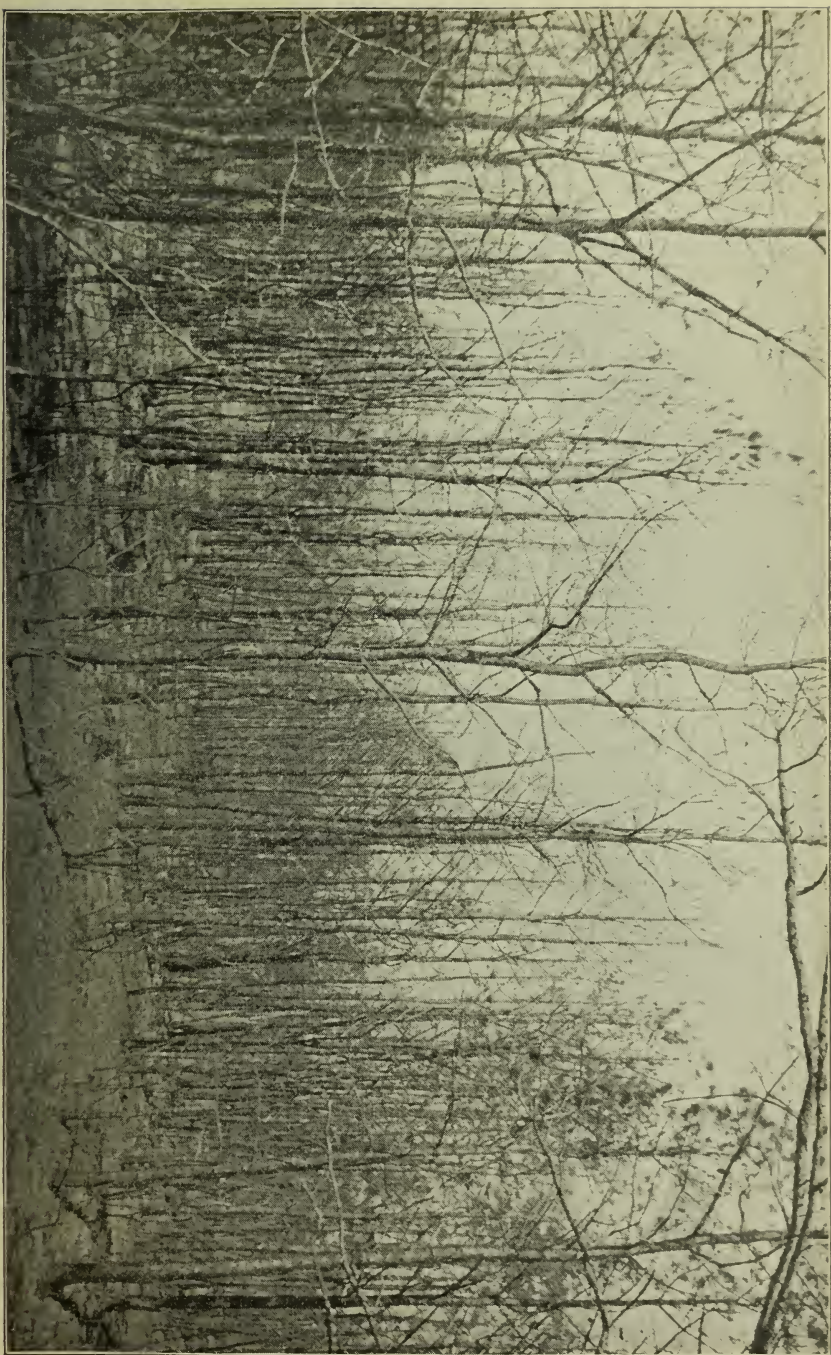
humus possess the power of absorbing water, vapor, and heat, but it has the ability to absorb some of the most important food materials of plants as well. Thus nitrates, phosphates, ammonia, etc., are held in solution ready for the use of the plants. Without humus many of the most important mineral materials would be washed away, especially from the loose soil of South Jersey.

Humus acts further as a reservoir from which food materials may be obtained, and by means of which they may be made ready for the use of the tree in growth. The final products of the decomposition of the humus are the mineral ashes, carbonic acid gas, and water. Through the ashes of the leaves, twigs, etc., a large amount of the most important materials used in the manufacture of wood are returned to the soil, and that in the most usable form. The carbonic acid gas acts powerfully toward the disintegration of the soil and in making the food constituents soluble, and in many sandy soils the value of its presence is very great. Thus the humus is really a manure to the forest.

If this layer of vegetable mold is destroyed the soil is impoverished at once. It loses one of the most powerful agents in its decomposition, loses its activity also, and finally becomes practically dead. In Europe it has been long recognized that the presence of humus is very beneficial to the forest, and its absence disastrous. This has led to laws forbidding the removal of the litter by peasants. The experience of the Germans has taught them that when the litter is continually taken away the forest becomes more and more open, the sun's rays and a freer circulation of air are admitted, the humus disappears, the soil dries out, and the trees become short, scrubby, and short-lived. Further, the soil eventually becomes so impoverished that trees which were at first produced are replaced by less fastidious and usually less valuable species. Thus in many parts of Germany, where formerly hard-woods thrived, now Pine is the only species that can profitably be grown.

It is not necessary, however, to go to Germany to see the effect, of the destruction of humus on the welfare of the forest. Abundant illustration is found in South Jersey. The conditions are somewhat different from those in Europe, for there the litter is removed from the forest by the peasants, while here it is burned on the ground. The mineral substances remain, but when the humus is destroyed they are probably, for the most part, washed away in the deep porous sand.

Plate V.—Pines Recently Killed by Fire. The Photograph was Taken While the Ashes Were Still Warm. Near McKee City, N. J.



The most serious injury from fire in New Jersey is its effect on the reproduction of the forest. Hope is frequently expressed for the future of the Pine in New Jersey because the Pitch Pine springs up so persistently after fire. It is true that throughout the fire-scarred tracts small Pine appears in great profusion after fires, but a close examination reveals the fact that in many cases these are not seedlings, but sprouts from the stools of the trees which were apparently killed. It is true that seeds germinate quickly on the sandy soils because of the capacity of the soil to become readily heated. But where the bare soil is exposed to the scorching sun and wind, as on large stretches of land in the coastal regions of South Jersey, it is difficult for seedlings to survive.

MORAL EFFECT OF FIRES ON POPULATION.

It is obvious that where the forest is constantly exposed to fire and there is no adequate protection, its value must be greatly depreciated. The result is that the timber is often cut before its maturity. Land-owners believe that with proper protection against fire the value of forest property will be greatly increased.

The fires have been so abundant that the people have come to look upon them as inevitable, and there is a deplorable lack of real interest among land-owners in regard to any attempt to introduce State protection. Large tracts of land are owned by non-resident capitalists, and timber-stealing is very common, especially after fires. When the timber is killed many persons consider it better to use the dead trees for cordwood than to allow them to rot on the ground, and they cut such timber on tracts of land to which they have no right. There is no doubt that forest fires encourage a spirit of lawlessness and a disregard of property rights.



Plate VI.—Pitch Pine Sprouting in the Crown Three Years After a Fire Which Killed all the Leaves. Ocean County, N. J.

III.

EFFECT OF FIRE ON THE FOREST PRODUCTION.

All who are familiar with the conditions of South Jersey know, from their own observation or from what has been written, that forest fires are very common and enormously harmful. But the extent of the damage is not often fully comprehended, for the devastated lands are compared with the forests which are now in existence and not with those which grew originally and which might still be flourishing if the land had been protected. It was the purpose in this investigation to determine by actual measurements the condition of the forest on burned areas, and to compare it with forest which had been protected from fire. A large number of sample plots, mostly of one acre each, were surveyed in different sections, the trees carefully measured, and notes were made of the height, age, density, condition, etc. From these valuation surveys, the results of which are summarized below, an accurate picture of the forest under different conditions can be obtained, and the deterioration of the forest can be traced step by step from the heavy timber 200 years old to the barren wastes, with scattered fire scarred Pine sprouts and scrub Oaks, which are so abundant in South Jersey.

THE ORIGINAL TIMBER.

The greater part of southeastern New Jersey was originally covered with a heavy growth of Pine. The poorer soils were probably occupied by Pitch Pine, the medium and better soils by Shortleaf Pine and hardwoods, and the deep swamps by Cedar.

From a study of scattered old timber, it is estimated that the original mature Pine forest yielded on an average from five to ten thousand board-feet per acre. This timber was about 150 to 200 years old and 15 to 20 inches in diameter, with occasional trees as large as

24, or even 30 inches. The average height of the old timber was 65 to 70, and the maximum 80 to 90 feet. The forest was open, with comparatively little undergrowth. It probably had a density of 0.6 to 0.8, if we consider that of a fully stocked stand to be 1.0. The seventeen sample plots in the summary, on page 25, show the condition of the original forest.

SECOND GROWTH.

When this timber was cut off, a second growth of Oak and Pine took its place on the better soils, while on poor soil Pitch Pine was the principal species. The second growth was chiefly of seedling origin.

From the time of the first heavy cutting, fires began to play an increasingly important part in the development of the forest. When the young trees were killed back by cutting or burning, the stumps, both of the hardwoods and the Pitch Pine, sent up sprouts. Where the land was protected from fire, seedlings returned and a thrifty second growth resulted, but when fires continued to run the few seedlings which crept in were in turn killed back, and afterward sprouted again; many trees were entirely killed; the forest became thinner and thinner; the ground clothed itself with a dense growth of huckleberries, scrub Oaks and dry-land moss, or the soil was completely laid bare; and land which once produced heavy timber was made almost worthless. It requires but a glance at the surveys taken on badly-burned land, *i. e.*, those of Table 3, to see, in the number of trees, the yield per acre, and the density, the deplorable condition of the forest.

CONCLUSIONS DERIVED FROM THE VALUATION SURVEYS.

For the acres in Table 3 the density averages 0.3, the number of trees per acre 133, and the yield 2.9 cords. From the study of second-growth timber which has not been burned, it is clear that the density would be 0.7 to 0.8 if the tract had been protected from fire. If we assume that the trees on the protected tract were sprouts there would be about three times as much wood per acre. If the trees were from the seed there would be, at forty years of age, on land fully stocked, about 1,200 trees and not less than 20 cords per acre, or about six times as much as is now produced. Further, the

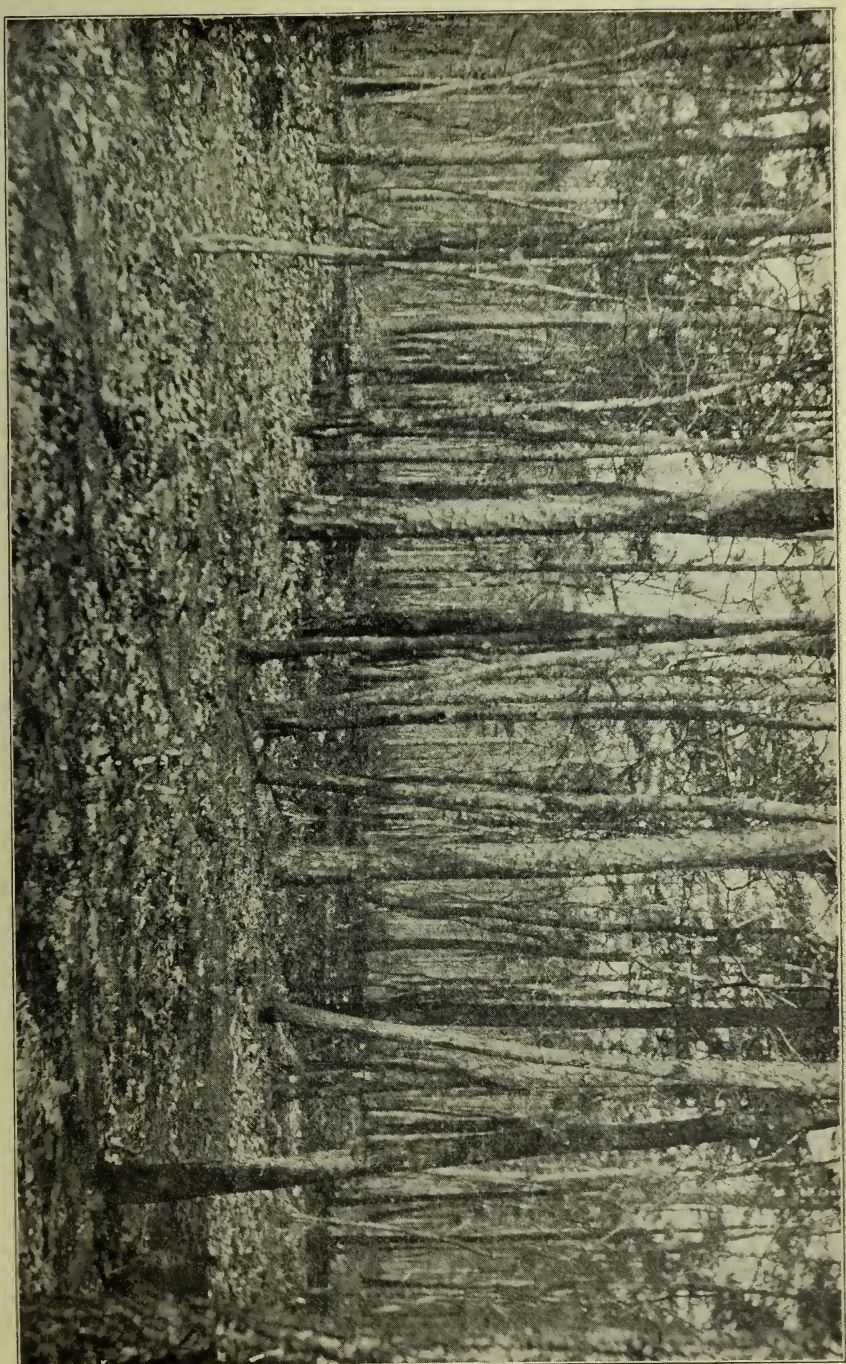


Plate VII.—Original Pine Forest at New Lisbon, New Jersey.

timber now found is coarse and knotty and fit for nothing better than cordwood, while in dense stands the trees are straight and clear of knots.

The burned land represented by the acres in Table 3 is then producing about one-third of the volume it would if protected from fire, and about one-sixth of what it is capable of yielding under careful management, while in quality and price the wood is very much inferior to the product of a healthy forest on the same ground.

Summary of Forty-nine Valuation Surveys, Showing the Deterioration of the Forest through the Effects of Fire.

TABLE I.

ORIGINAL FOREST.

Plot No.	No. of trees per acre.	Average diameter. Inches.	Average diameter over 6 inches. Inches.	Average age. Years.	Yield per acre. Board Feet.	Density.
1.....	67	.....	13.9	100-200	10,170	0.7
2.....	70	.....	14.0	" "	9,925	0.6
3.....	78	.....	13.0	" "	8,940	0.6
4.....	86	.....	12.7	" "	8,828	0.7
5.....	113	.....	10.0	" "	8,000	0.6
6.....	92	.....	12.0	" "	7,739	0.6
7.....	65	.....	13.0	" "	7,521	0.6
8.....	71	.....	12.4	" "	7,488	0.6
9.....	68	.....	12.5	" "	7,208	0.6
10.....	104	.....	11.2	" "	6,134	0.7
11.....	97	.....	10.2	" "	5,760	0.6
12.....	45	.....	13.1	" "	5,631	0.5
13.....	80	.....	10.1	" "	5,200	0.6
14.....	85	11.0	" "	4,618	0.55
15.....	97	10.7	" "	4,500	0.6
16.....	245	9.0	" "	3,700	0.7
17.....	74	10.4	" "	3,369	0.55
Average	91	11.7	6,631	0.6

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TABLE 2.

SECOND GROWTH ON LAND PROTECTED FROM FIRE.

Plot No.	No. of trees per acre.	Average diameter. Inches.	Average diameter over 6 inches. Inches.	Average age. Years.	Yield per acre. Board Feet.	Yield per acre. Cords.	Density.	REMARKS.
18	286	.....	8.6	80	7,397	.....	1.0	Seedling second growth.
19	323	.....	8.9	80	7,604	.....	1.0	"
20	364	9.8	.....	50	.....	48	0.8	Chiefly from seed.
21	482	6.6	.....	40-60	.....	34	0.7	"
22	573	5.2	.....	" "	.....	21	0.8	"
23	279	6.6	.....	55 (est.)	.....	20	0.7	Seedling second growth.
24	1,088	4.4	.....	40 (est.)	.....	20	0.9	"
25	724	4.8	.....	40-60	.....	20	0.95	Chiefly from seed.
26	532	5.3	.....	" "	.....	18	0.75	"
27	559	4.8	.....	" "	.....	16	0.8	"
28	410	5.3	.....	" "	.....	14	0.7	"
29	988	3.7	.....	35-40	.....	13	1.0	Sprouts.
30	521	3.9	.....	" "	.....	7	0.8	"
Average	548	5.5	8.8		7,500	21	0.8	

TABLE 3.

SECOND GROWTH ON LAND BADLY BURNED.

Plot No.	No. of trees per acre.	Average diameter. Inches.	Average age. Years.	Yield per acre. Cords.	Density.	REMARKS.
31.....	105	7.0	30-40 (est.)	7.5	0.5	Chiefly Sprouts.
32.....	339	4.7	.....	7	0.6	"
33.....	98	6.4	30-40 (est.)	5	0.2	"
34.....	189	4.8	" "	4.2	0.3	"
35.....	191	4.8	" "	4.2	0.2	"
36.....	94	5.7	" "	3.1	0.2	"
37.....	121	4.9	" "	2.8	0.2	"
38.....	221	3.1	20-30 "	2.7	0.1	"
39.....	200	3.6	30-40 "	2.6	0.4	"
40.....	73	5.5	25-30 "	2.3	0.1	"
41.....	177	3.4	20-30 "	2.2	0.1	"
42.....	118	4.4	30-40 "	2.2	0.4	"
43.....	114	4.4	" "	2.1	0.3	"
44.....	191	2.9	" "	2.1	0.2	"
45.....	90	4.5	" "	1.7	0.2	"
46.....	135	3.2	20-30 "	1.6	0.3	"
47.....	42	5.5	30-40 "	1.3	0.2	"
48.....	26	4.2	30 "	0.4	0.1	"
49.....	14	5.5	" "	0.5	0.1	"
Average ...	133	4.8	.....	2.9	0.3	

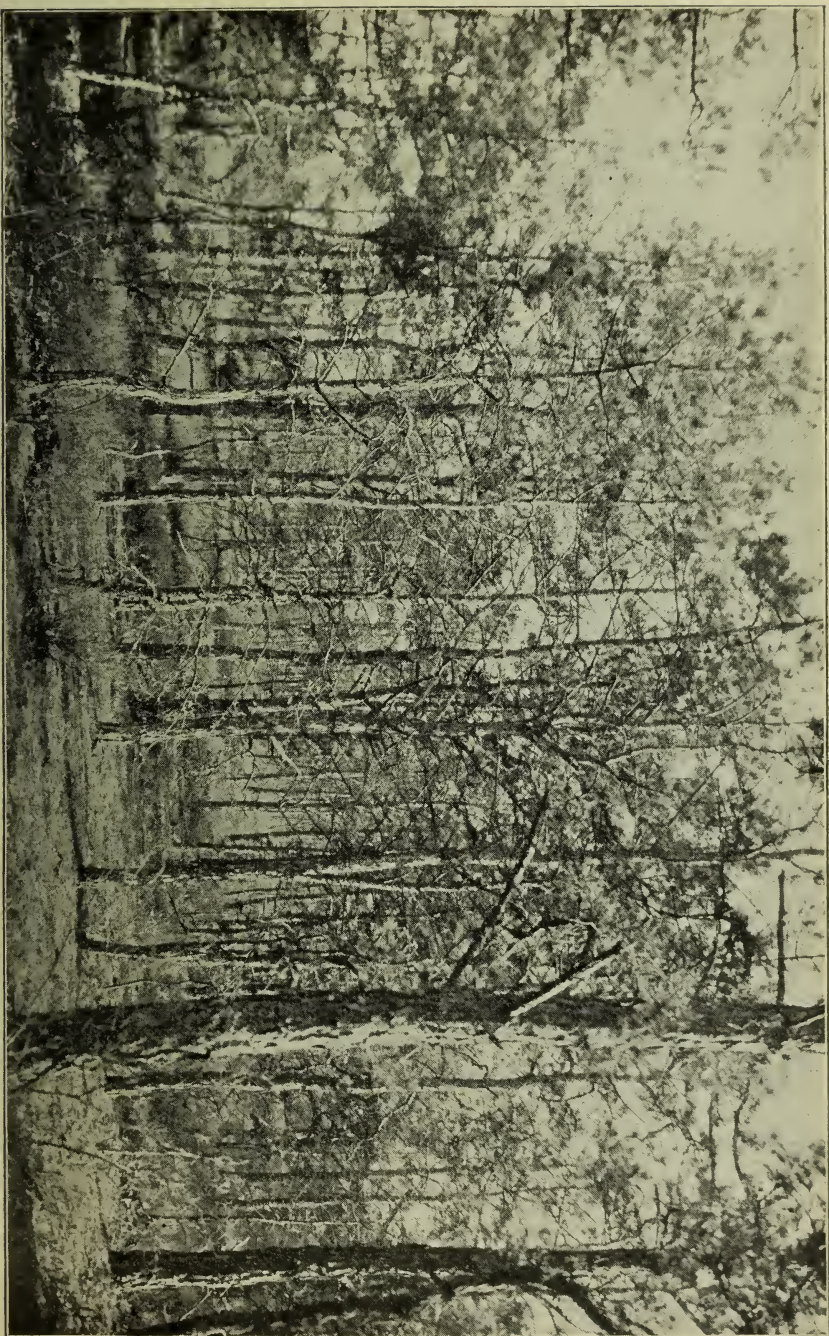


Plate VIII.—Second-Growth Pitch Pine of Average Quality. Ocean County, N. J.



DESCRIPTIONS OF REPRESENTATIVE AREAS.

The following detailed descriptions of the measurements taken in different parts of South Jersey contain the essential facts from which the conclusions in the preceding sections were drawn. They illustrate the methods used in the investigation and give some indication of the localities studied and of the amount of labor involved.

Original Forest at Winslow.

A satisfactory understanding of the loss occasioned by forest fires in South Jersey presupposed a knowledge of what the land is capable of producing when uninjured by burning. To acquire such knowledge was not easy.

There are comparatively few places where original Pine can still be found, and in these the soil is apparently better than on the fire-scarred areas now covered with straggling, scrubby second growth. These places may, however, be used to illustrate the original conditions, for the soil on areas now fire-scarred was doubtless more productive when covered with a rich layer of forest litter than it is now; and while the original trees over the greater part of South Jersey were probably for the most part Pitch Pine, the yield per acre probably did not fall far short of that of the Shortleaf (locally called Yellow) Pine now found on the areas studied, the fertility of which was somewhat above the average.

One plot of old timber situated near Winslow is owned by Mr. J. H. Rosenthal, of Philadelphia. The large Pine was being cut for the market while this plot was being studied, and the measurements were taken as the trees were sawed into logs. In this forest the Yellow Pine predominates, but there are considerable numbers of Pitch Pine as well. The Pine occurs both in patches and scattered over the area, and is associated with small Oaks and a few larger ones. The trees reach a diameter of two and a height of eighty-five feet. The larger Oaks, White and Chestnut, in some cases reach a diameter of thirty inches, while among the smaller trees Black and Post Oaks are found. The soil is a white sand, with a slight admixture of loam on the better portions. In this forest there were measured twelve sample acres, a summary of which is given in Table 5 below. The following sample acre is given in full and

furnishes a very good mental picture of the average conditions in this forest.

TABLE 4.

One Acre Measured Near Winslow, New Jersey.

Diameter, breast high.	Pine, including stumps.	White Oak.	Black Oak.	Chestnut Oak.	Post Oak.	Hickory.
3 Inches.....	1	26	7	...	...	2
4 "	2	12	14	4	...	...
5 "	2	10	15	2	...	...
6 "	2	8	21	2	...	1
7 "	6	4	12	1	...	...
8 "	2	6	3	1	...	...
9 "	4	6	1	1	...	...
10 "	4	4	1	2	1	...
11 "	4	...	1	2	...	...
12 "	14	1	...	...	...	...
13 "	5	1	...	...	...	...
14 "	8	1	...	...	...	...
15 "	5	...	...	...	...	1
16 "	2	...	...	...	...	...
17 "	6	...	...	...	...	...
18 " .....	...	...	...	...	...	...
19 "	1	...	...	...	...	...
20 " .....	...	...	...	...	...	...
	68	79	75	15	1	4

Average height of Pine, 68 feet. Diameter of the average tree over ten inches, 13.7 inches. Total volume, 2,127 cubic feet. Total merchantable volume over ten inches, 7,203 board feet. Yield of hardwoods, 7.0 cords (est.).

Soil, dry sand. Flat. Undergrowth composed of young Oaks and a few Pine seedlings. Humus rather poor. Density, 0.6 of the normal.

The following table gives a summary of the twelve acres studied at Winslow. The merchantable trees are of various ages, from 120 to 200 years old. It will be seen that there are on an average about 45-50 trees per acre over 10 inches, with an average yield of about 7,000 board feet.

TABLE 5.

*Summary of Measurements on Twelve Acres of Old Pine at Winslow,
New Jersey.*

Plot number.	Number of trees.	Number of trees over six inches.	Average diameter breast high.	PINE.						HARDWOODS.		
				Number of trees over ten inches.	Average diameter breast high.	Maximum diam- eter breast high.	Average height	Total volume over six inches.	Merchantable volume over ten inches.	Number of trees.	Average diameter breast high.	Cords (estimated).
			Inches.		Inches.	Inch's	Feet.	Cu. ft.	Bd. ft.		Inch's	
1	67	66	13.9	34	14.4	22	69.1	2,882	10,170	140	5.9	6.5
2	70	65	14.0	51	16.2	18	63.8	2,917	9,925	96	6.2	5.0
3	78	72	13.0	56	14.8	18	66.9	2,812	8,940	137	5.6	5.5
4	86	74	12.7	56	13.9	20	69.7	2,548	8,828	161	5.9	7.5
6	92	78	12.0	55	13.4	18	68.1	2,557	7,739	183	6.9	13.5
7	65	60	13.0	46	14.3	21	67.5	2,228	7,521	121	6.8	8.5
8	71	69	12.4	54	13.5	19	66.3	2,388	7,488	120	7.0	9.5
9	68	63	12.5	49	13.1	19	68.1	2,127	7,208	174	5.7	7.0
10	104	78	11.2	51	12.6	17	68.1	2,048	6,134	124	6.4	7.5
12	45	43	13.1	35	14.1	20	68.1	1,613	5,631	6	6.3	0.3
14	85	62	11.0	35	13.1	19	66.8	1,708	4,618	147	6.9	11.0
17	74	57	10.4	27	12.8	16	66.8	1,275	3,369	159	6.3	9.0

Original Forest at New Lisbon.

Another forest of old Pine was found at New Lisbon, on the estate of Mr. Black. Here, as at Winslow, the Pine was scattered in patches, mixed with Oaks, and as before, the Shortleaf Pine predominated. The average yield of Pine on the five acres measured was about 5,500 board feet and the number of trees per acre over ten inches in diameter about fifty. The following sample acre will serve to illustrate the forest in this section. This plot is figured in Plate VII.

TABLE 6.

One Acre Measured in Old Pine Near New Lisbon, New Jersey.

Diameter breast high.	Pine, including stumps.	White Oak.	Black Oak.	Chestnut Oak.	Post Oak.
1 Inches.....	3	18	7	5	...
2 "	1	18	13	19	2
3 "	8	13	13	24	...
4 "	5	14	10	26	...
5 "	2	7	10	24	1
6 "	5	13	10	6	...
7 "	7	3	...	8	1
8 "	2	1	3	...	...
9 "	6	1	...	...	...
10 "	7	2	...	...	...
11 "	5	1	...	...	...
12 "	17	1	...	...	...
13 "	7	...	...	...	...
14 "	4	...	...	...	...
15 "	6	1	...	...	...
16 "	1	1	...	...	...
17 " .....	...	...	...	...	...
18 " .....	...	...	...	...	...
19 "	2	...	...	...	...
	88	94	66	112	4

Average height, about 65 feet. Diameter of the average tree over ten inches, 12.8 inches. Yield of Pine over ten inches, 5,200 board feet; of small Pine, 1.1 cords; of Oaks, 3.5 cords. Soil, dry white sand. Flat. Burned over every spring, and underbrush killed. Density, 0.6 of the normal.

TABLE 7.

Five Acres Studied at New Lisbon.

Plot No.	No. Pine, including stumps.	No. Pine over 10 in.	Ave. Diam. breast high. Inches.	No. Pine under 10 in.	Ave. Diam. breast high Inches.	Merch. Pine. Board feet.	Small Pine. Cords.	No. Oak.	Ave. Diam. breast high. Inches	Yield. Cords.
5	113	46	15.1	86	4.9	8,000	2.6	130	3.0	1.3
11	97	64	11.8	51	6.2	5,760	2.8	233	3.9	3.5
13	80	52	12.8	39	4.7	5,200	1.1	276	3.8	3.5
15	97	53	12	44	5.2	4,500	1.5	383	4.0	6.0
16	245	37	12	208	3.4	3,700	3.8	119	3.1	1.0

SECOND GROWTH.

When land of this character is cut over it is usually followed by a growth of hardwoods and Pine on the medium and better soils, and, on the areas less adapted to hardwoods, by Pitch Pine. Pine gradually creeps back on the areas which have come up to hardwoods and in many cases crowds them out. Often the Pine seeds an old field with good soil very abundantly, and a pure forest springs up. Such a patch was found nearly fully stocked at Winslow, and two acres are given in detail on pages 52 and 53. This forest is a nearly even-aged stand of Shortleaf (Yellow) and Pitch Pine, the former predominating, about eighty years old, and gives an admirable picture of what a normal stand of Pine can produce. A full discussion of the tract is found with the surveys. It is exceedingly interesting to compare this stand with the old forest at Winslow. It will be seen that the yield in board feet is just as large for trees over ten inches, and that the yield (over six inches) is about twice as large, while the trees are only about one-half as old.

Such stands as this are the great exception, for the reproduction of the forest has been left to take care of itself, the trees have been cut with no regard whatever to the next crop, and fires have swept over the ground repeatedly, destroying young growth and thinning the old timber, so that as a rule the second growth forest is open and straggling. The soil is abundantly able, for the most part, to produce merchantable timber, in spite of repeated fires and bad cutting. These latter, and not the soil itself, are responsible for the present poor condition of the forest, which needs only protection and judicious cutting to regain its value in the end.

Second Growth at Whitings.

A number of acres of second growth studied near Whitings are exceedingly interesting, both as to their origin and their growth and development. The surveys given below were taken about two miles southeast of Whitings, on a private tract of about one thousand acres. The forest is a pole wood of high density, containing trees of two age classes, one about fifty to sixty, the other thirty to forty years old. The larger trees have every appearance of being of seedling origin. The smaller trees seem like sprouts, for they

are crooked and contorted, and of very slow growth. There are, further, many small, twisted trees, thirty to fifty years old, and only one to two inches in diameter, which spread out in umbrella form at about six to eight feet from the ground. It is reasonably certain that these are stunted sprouts, which manage to live in the shade of the pole woods and grow only enough to maintain their existence.

The humus is deep and the soil a dry white sand. There has been no fire for many years, the tract having been successfully protected by careful watching.

The average height of the older class of trees is forty-five, of the younger thirty-six feet. The rate of growth for the older tree is one inch in diameter in fifteen years, of the smaller trees one inch in twenty years.

Although it is extremely difficult to determine definitely whether the older trees on this area are seedlings or sprouts, the conclusion arrived at from study here and elsewhere is that they are seedlings. The old stumps probably have a limited capacity for sprouting. It is the roots of the second and third growth and the succeeding generations that produce sprouts freely. The following sample acre will serve to illustrate the character of this second growth :

TABLE 8.

One Acre Measured Near Whiting's, New Jersey.

Diameter breast high.	Pine.
1 Inches	18
2 "	30
3 "	44
4 "	43
5 "	76
6 "	80
7 "	30
8 "	40
9 "	21
10 "	17
11 "	9
12 "	2
	<hr/>
	410

Yield of Pine, 140 cords (est.). Average diameter, 5 3 inches. Soil, white sand. Slope, gentle to northwest. Undergrowth, Huckleberries and Ground Oak. Humus, deep. Density, 0.7 of the normal.

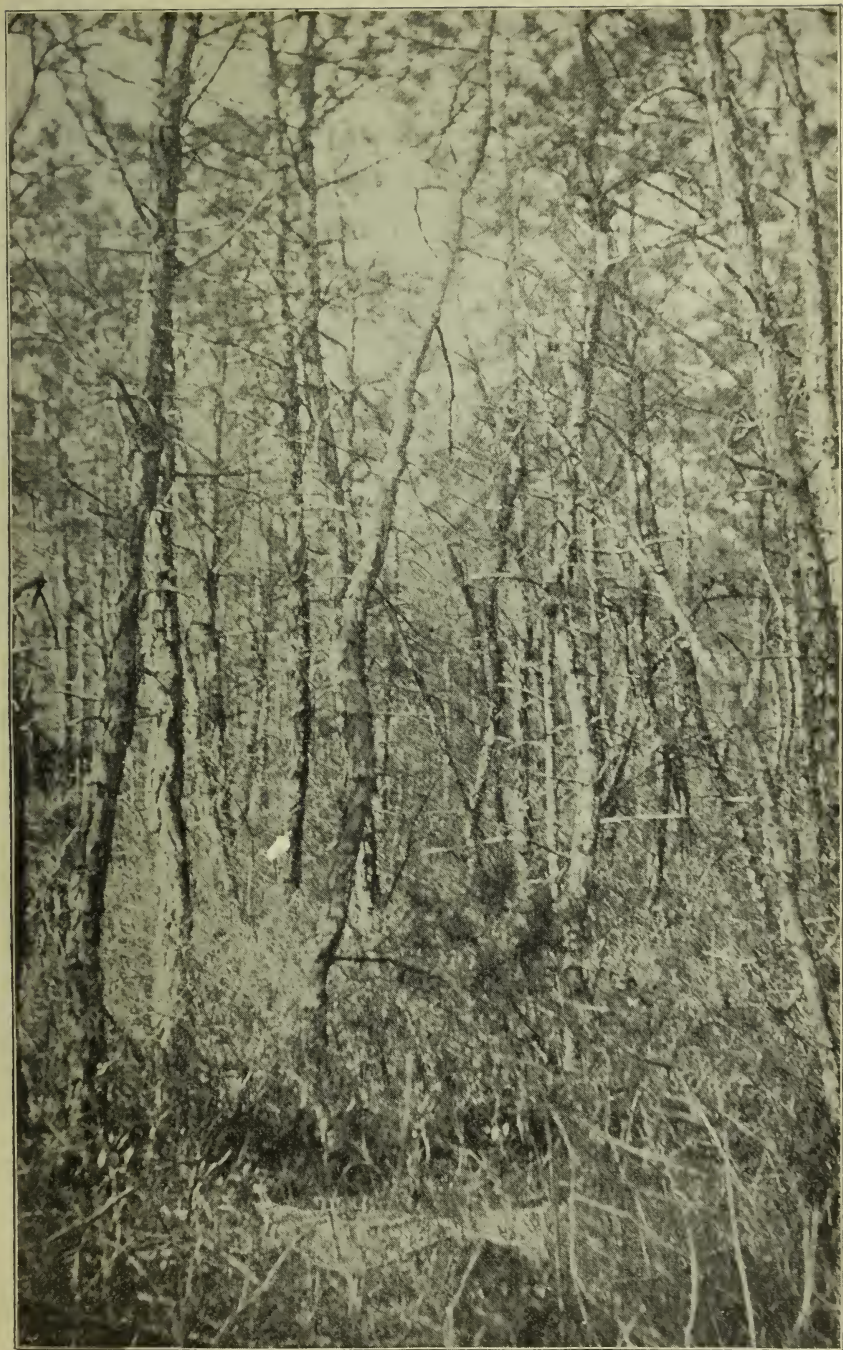


Plate IX.—Young Pine Sprouts. Average Diameter Four Inches; Average Height 25 Feet. About 35 to 40 Years Old. Ocean County, N. J.

TABLE 9.

Six Surveys at Whitings, N. J.

Plot No.	No. of Pine.	Area. Acres.	Average diameter breast high. Inches.	Maximum diameter breast high. Inches.	Yield Cords.	Yield per acre. Cords.
21	241	$\frac{1}{2}$	6 6	11	17	34
22	573	1	5 2	13	21	21
25	362	$\frac{1}{2}$	4 8	11	10	20
26	266	$\frac{1}{2}$	5 3	12	9	18
27	559	1	4 8	12	16	16
28	410	1	5 3	12	14	14

Pine Sprouts at Whitings.

In discussing the question of sprout Pine growth it is instructive to study both verbal and visual pictures of an area which is surely of this origin. This forest is about one mile west of the preceding acre, and is probably of the same age as the smaller trees on that plot. Plate IX illustrates the contorted straggling growth. The young polewood has a density nearly normal, and the soil is a dry white sand. There is an undergrowth of huckleberries and Scrub and Post Oaks, but the area has not been burned over and the humus is excellent.

TABLE 10.

One-quarter acre of Pine Sprouts, 35 to 40 Years Old, Near Whitings, N. J.

Diameter.	No. of trees.
2 Inches.....	40
3 "	85
4 "	62
5 "	42
6 "	12
7 "	5
8 "	1
	<hr/>
	247

The average age of the crop is 35 to 40 years ; the average height, 24 feet ; the average diameter, 3.7 inches. It is fair to ask why the growth is slow. The soil, it is true, is a dry sand, but similar soil has been observed to bear very much more rapidly growing trees.

Fire has never touched the trees and there is a deep humus. The reason has already been given. The trees are twisted and crooked and often with from two to five stems apparently from the same root, and the forest is composed of Pine sprouts. The yield of this area is estimated to be thirteen cords per acre.

Not far from this plot a small area was studied where the wood had been cut and stacked. The trees were not nearly so numerous, and fire had apparently run over the area at some time, though not of late. The stumps were measured on 0.3 of an acre.

TABLE 11.

Diameter on stump.	No. of trees.
2 Inches.....	27
3 "	50
4 "	47
5 "	17
6 "	17
7 "	9
8 "	1
	<hr/> 168

The stacked wood measured slightly over two cords, or about seven cords per acre. Six stumps were studied, and the age was found to be thirty-five to forty years on the stump.

The growth of an average stump was 0.6 inches in diameter in the last ten years, or at the rate of one inch in about seventeen years.

Second Growth After Fire.

The sample acres given above show what the original forest probably produced and what the second growth yields, whether of seedlings or sprouts, where the land has not been very severely burned. It remains to show the condition of land which has been repeatedly burned, and to trace the various stages of deterioration from the condition described above to the desolate stretches of sand-barrens in some sections of Ocean county.

The first stages of deterioration of the forest may be illustrated by the valuation survey which was taken near West Creek, Ocean county, New Jersey. The soil is a fine white sand, with a moderate layer of humus. The land has been burned a number of times, but

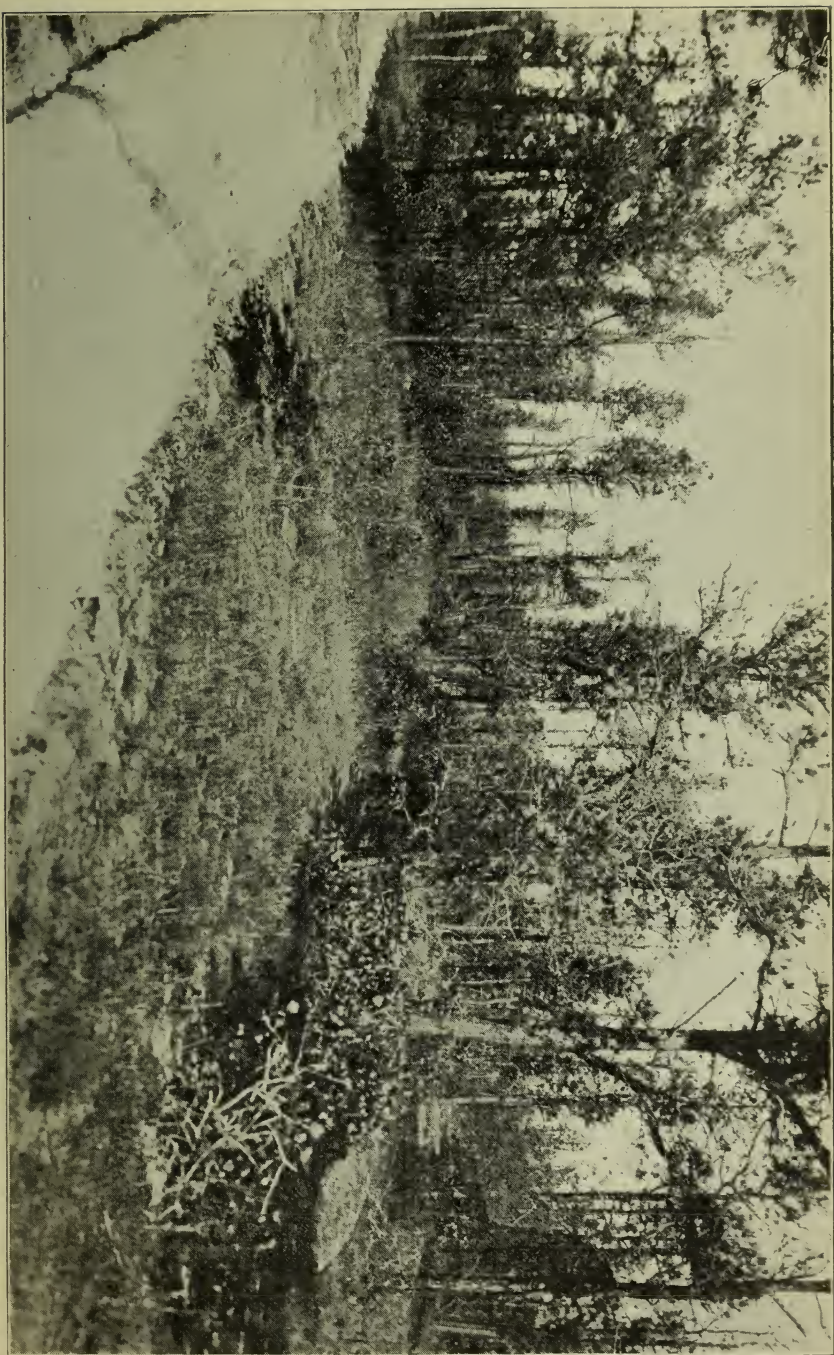


Plate X.—Pitch Pine Forest Thinned by Fire. Ocean County, N. J.

the fire has been chiefly confined to the surface. The general character of the forest is similar to that shown in Plate X. It will be seen that the trees are very coarse and scrubby, and that while there is a fairly large number per acre, the diameters are small and the trees stand too far apart for good natural pruning to take place. The ground is covered with huckleberries and Scrub Oaks between the Pines. These trees are probably about thirty to forty years old. In a normal stand of this age there should be not less than nine hundred to one thousand stems per acre.

TABLE 12.

*One Acre Measured in Second-Growth Pine Near West Creek,
Ocean County, N. J.*

Diameter.	No. of trees.
2 Inches.....	22
3 "	56
4 "	88
5 "	72
6 "	60
7 "	33
8 "	8
	<hr/> 339

Number of Pine under two inches, 73.

Number of Oak under two inches, 389.

Average diameter of the Pine, 4.7 inches.

Yield of Pine estimated to be about seven cords.

The next stage in the decline of the forest is well illustrated by the valuation survey below, and by Plate XI. This survey was taken near Onga's Hat, Burlington county. The area has been burned many times, and the trees are scrubby and scattered. There is but little undergrowth, and almost no humus, and even Scrub Oaks find difficulty in growing. The number of trees is even less than before. The photograph is taken near Tuckerton, but shows the same stage in the deterioration of the forest as the valuation survey.

TABLE 13.

*One Acre Measured in Second-Growth Pine Near Ongs Hat,
Burlington County, New Jersey.*

Diameter.	No. of trees.
2 Inches.....	35
3 "	7
4 "	18
5 "	23
6 "	12
7 "	9
8 "	6
9 "	8
	<hr/> 118

Number of Pine under two inches, 108.

Number of Oak under two inches, 162.

Average diameter of the Pine, 3.7 inches.

Yield of Pine estimated to be about 1.6 cords.

Soil, gravelly sand. Flat. Density, 0.4.

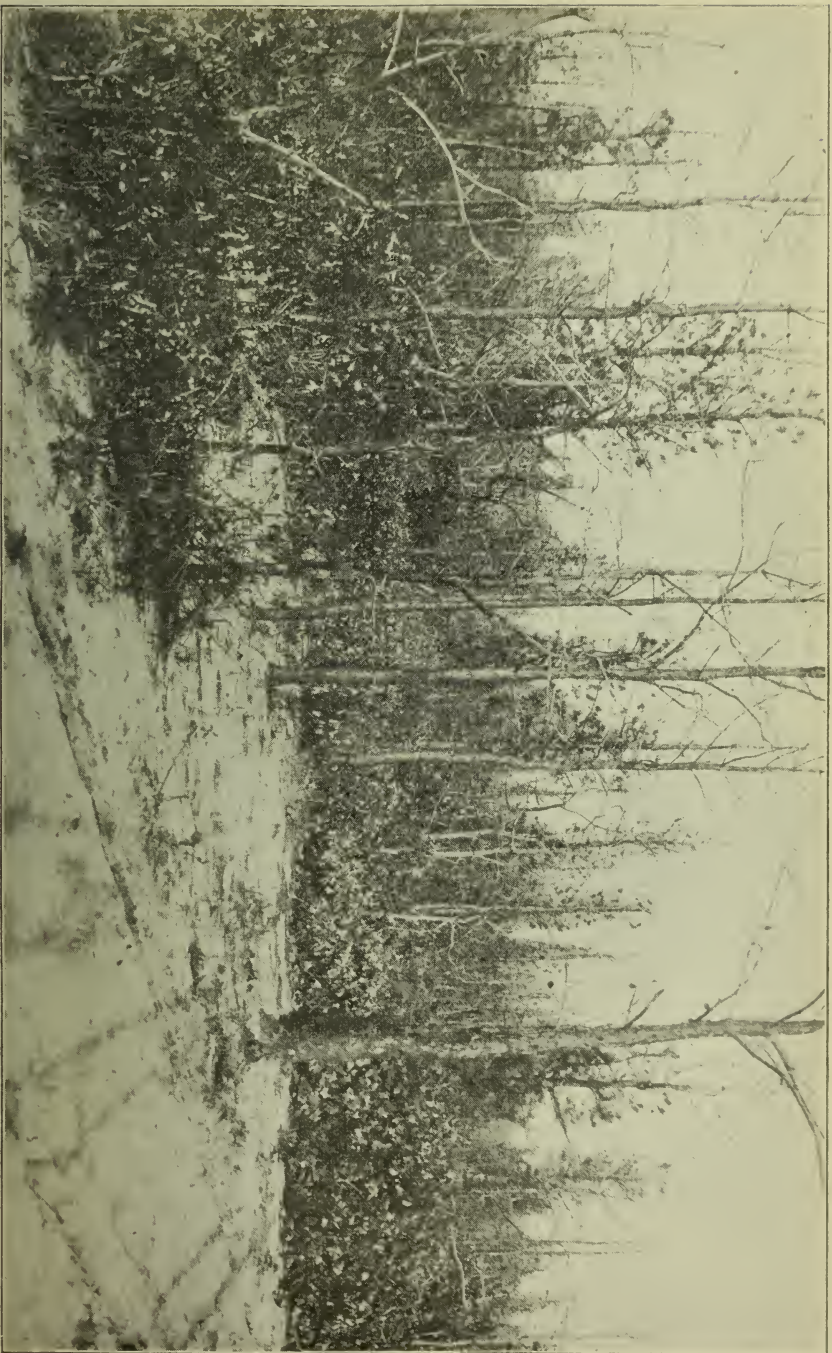
TABLE 14.

Nine Sample Acres Showing a Still Further Advanced Stage in the Deterioration of the Forest by Fire.

Plot No.	Pine over 2 inches in diameter.	Average diameter, breast high.	Maximum diameter breast high.	No. of cords.	Pine under 2 inches in diameter.	No. of small oaks.	Density.	LOCALITY.
		Inches.	Inches.					
31	105	7.0	14	7.5	74	113	0.6	Ongs Hat.
33	98	6.4	13	5.0	...	1	0.2	Ongs Hat.
34	189	4.8	8	4.2	68	208	0.5	Near East Plains.
36	94	5.7	12	3.1	...	...	0.2	Ongs Hat.
37	121	4.9	9	2.8	78	708	0.2	Near East Plains.
39	200	3.6	9	2.6	77	34	0.4	Spring Hill.
43	114	4.4	8	2.1	139	274	0.3	Tuckerton.
45	90	4.5	8	1.7	36	411	0.2	Near East Plains.
47	41	5.5	10	1.3	1	...	0.2	Ongs Hat.

The three sample acres in the next table show the condition of a younger forest, but one which has been more severely burned and is in a lower stage of decline than the preceding acres. The soil is dry and the humus has been almost entirely destroyed. The trees are all

Plate XI.—Badly Burned Pine, with Stunted Oak Sprouts Underneath. Burlington County, N. J.



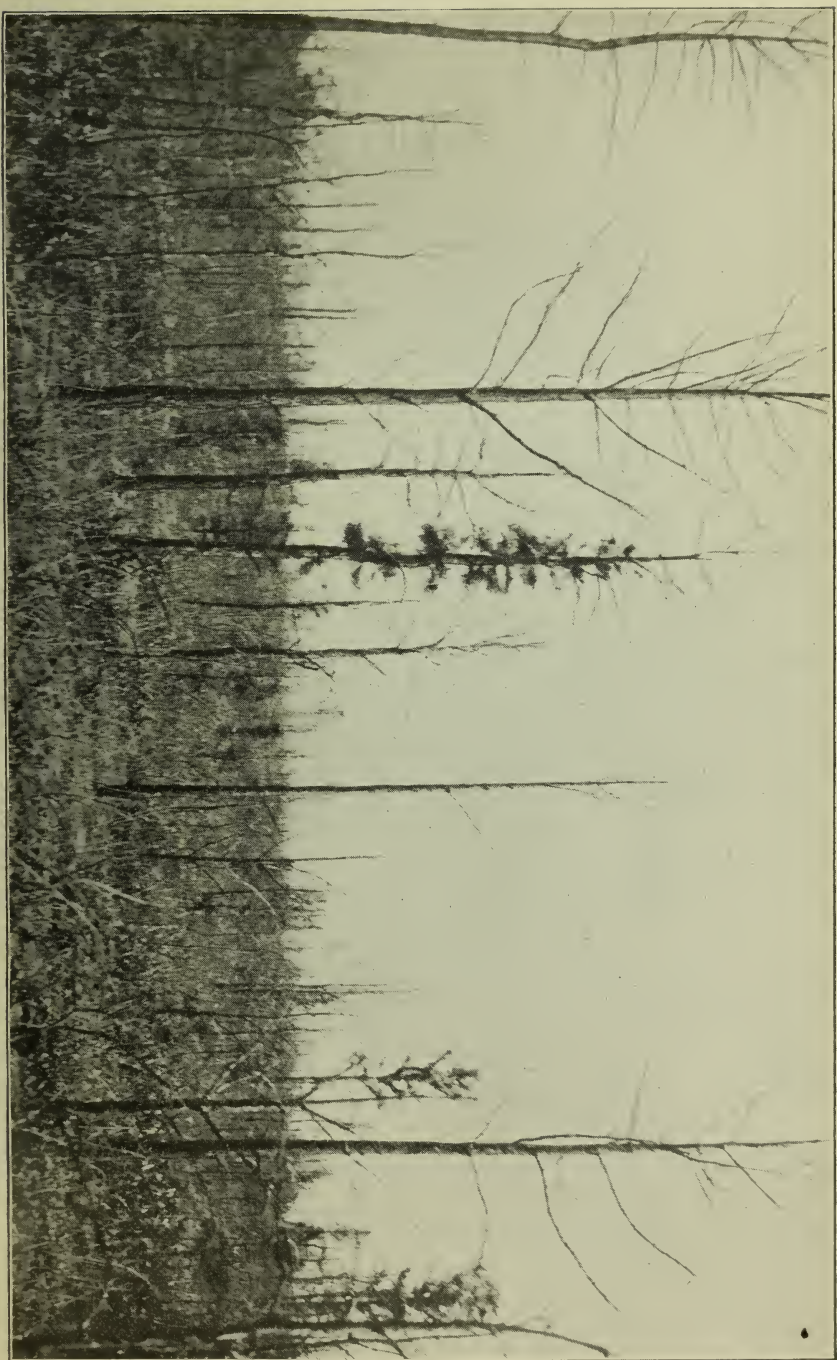


Plate XII.—Repeatedly Burned Land, with Sprouts of Oak and Pine. Tuckerton, N. J.

crooked and scrubby sprouts of Pitch Pine. There are large numbers of Scrub Oaks on the ground.

TABLE 15.

Three Sample Acres Showing a Very Advanced Stage in the Deterioration of the Forest Through Fire.

Plot No.	Pine over 2" in diameter. Inches.	Average diameter breast high. Inches.	Maximum diameter breast high. Inches.	Oak over 2" in diameter. Inches.	Average diameter breast high. Inches.	Pine under 2" in diameter.	Oak under 2" in diameter.	Density.	Locality.
38	221	3.1	5	...	...	466	312	0 4	Near East Plains.
41	177	3.4	6	...	...	386	250	0 1	
46	135	3.2	5	83	2.1	62	147	0.3	Spring Hill

By such steps as these the forest has been reduced from a fine old growth of merchantable timber to a straggling, scrubby growth of sprouts. The stage in deterioration next to the last is shown by four surveys taken on land near Tuckerton, which was burned in 1894, and the trees of which had apparently been killed, but had begun to sprout again from the crown and the base. The dead trees, those sprouting at the base and those sprouting in the crown, were all counted separately. Plate I well illustrates this plot. It is worth while to note that the larger trees are those which sprout in the crown and that the small trees sprout at the base.

TABLE 16.

Four Acres Measured Near Tuckerton, N. J., Burned Over in 1894.

Plot No.	Pine sprouting in crown.	Average diameter breast high. Inches.	Pine sprouting at stump.	Average diameter breast high. Inches.	Dead Pine.	Average diameter breast high. Inches.
40	26	5.5	121	4.8	23	6.4
48	73	4.2	130	1.9	230	2.4
49	14	5.5	.....	.....	Not	
56	7	6.0	....	.....	counted.	



Plate XIII.—General View of the East Plains.

IV.

THE PLAINS.

The East or Lower Plains are situated for the most part in Burlington county, between Tuckerton and the East branch of the Wading river. The West or Upper Plains lie nearly north of the East Plains, and are separated from them by this stream. The former cover 7,737 and the latter 6,662 acres.

The land is rolling, with high ridges and deep ravines. On the ridges the soil is a coarse, gravelly sand; in the hollows chiefly sand also, but rather fine in grain. The upper soil is extremely dry, and in places there is a hard subsoil at a depth of one to two feet.

The Plains are for the most part covered with a small and ragged growth of Pitch Pine, Scrub and Black Jack Oaks, Laurel, Bearberry and other small plants of the Heath family. The Pine and Oak are of three descriptions: 1st, a stunted, prostrate growth from two to four feet in height, which covers by far the largest part of the Plains; 2d, Pine from six to fourteen feet in height, very stunted and branching nearly to the ground, with a growth of Scrub Oak below. This growth covers a comparatively small part of the Plains. In many cases fire has killed the trees, and there is but little young sprout growth coming up, but where the land has not been burned so severely young shoots are abundant; 3d, the large Pine from fourteen to twenty-five feet in height, usually very crooked and scrubby, with a thick growth of Scrub Oak underneath. This growth is rare, and is found only in deep ravines or on the edge of Cedar swamps.

In many cases the Plains are terminated abruptly by large timber. Often, however, the growth merges gradually into that of the surrounding forest. In this case the Pine becomes progressively more erect, the soil takes on a covering of dry-land moss, humus, and shrubs, and the trees finally reach the size characteristic of the surrounding country.

The Pine is chiefly of coppice growth, that is, it consists of sprouts from the stumps or from the creeping branches of trees which have been killed back by fire. If the small specimens are carefully examined, however, it will be found that, although they have the appearance of sprouts, they are in many cases really seedlings, with stems and branches creeping on the ground. Sprouting stumps are found which have been killed back but once, as well as old gnarled burls, veterans of many burnings, covered with knobs from which protrude the charred stubs of dead branches and the new living shoots. Sometimes these burls are compact, almost globular, but more often they take the form of numerous creeping stems, radiating from a common root and sending out sprouts from the knobs of old scars at the end. Dead stumps are common which, in times past, have sprouted again and again, until at length they became exhausted and died. The age of the main root of a number of such stumps was counted and found to be as much as forty, sixty, and in one case at least one hundred years.

Within the limits of the Plains there are individual specimens of Pine which are erect and growing thriftily. On examination they are found to be healthy seedlings, standing generally in sheltered hollows.

The roots of the Pine on the Plains are often short and poorly developed. This is doubtless due to the lack of moisture and to the hard subsoil, which the roots apparently find difficulty in penetrating.

AGE OF THE PINE.

There is a prevailing opinion that the Pine coppice on the Plains is very old. The Plains are said to have been in their present condition since the country was first settled, and the conclusion is drawn that the trees are nearly two hundred years of age. It may be true that the barren stretches had much the same appearance two centuries ago that they now present, but the sprouts now on the ground are young. Fifty-five stems were cut on the West Plains and their age was counted, and fifty-three on the East Plains. These figures are given in the following tables:

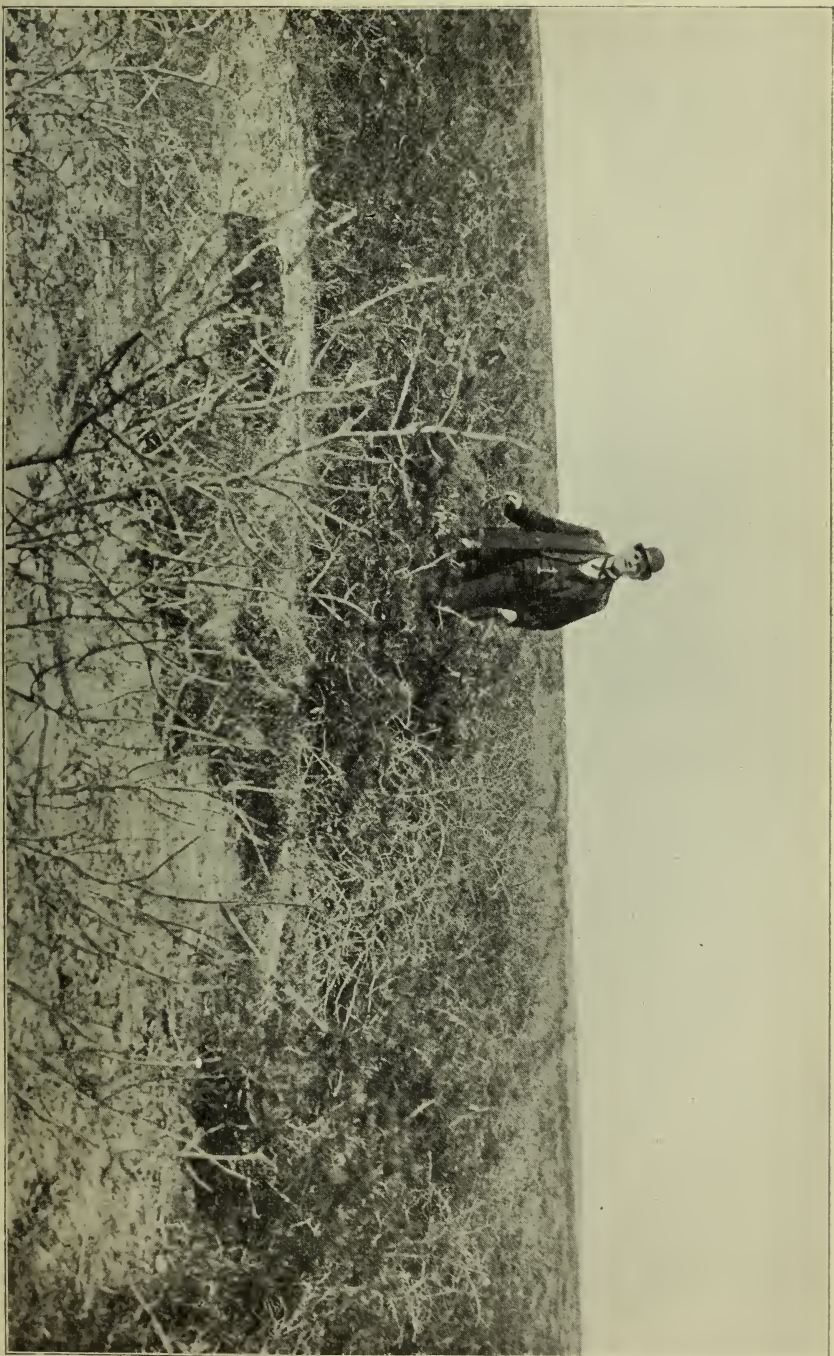


Plate XIV.—In the East Plains.

TABLE 17.

*Age of Pine Sprouts on the Lower or East Plains, Near Tuckerton,
Burlington County, New Jersey.*

Height. Feet.	Age. Years.	Height. Feet.	Age. Years.	Height. Feet.	Age. Years.
8	17	5 5.....	17	4	16
8	15	6	16	5	14
6	11	7	10	3 5.....	10
8	15	8	14	6	14
8	14	8 5.....	14	2 5.....	12
5	12	9	16	4	13
8 5.....	20	6	14	6 5.....	18
6	11	8	13	7	19
6	9	3 5.....	11	2	9

TABLE 18.

Age of Larger Pine Growing Within the Limits of the Lower Plains.

Height. Feet.	Age. Years.	Height. Feet.	Age. Years.	Height. Feet.	Age. Years.
11	30	11	23	17	38
10	13	13	36	17	41
12	16	13	40	19	43
11 5.....	15	12	27	21 5.....	41
12	24	12	28	17	33
20	40	11 5.....	28	10	22
13	24	21	40	10 5	22
21	46	18	39	13	19
17 5.....	42			10	22

TABLE 19.

*Age of Pine Sprouts on the Upper or West Plains, Near Chatsworth,
Burlington County, New Jersey.*

Height. Feet.	Age. Years.	Height. Feet.	Age. Years.	Height. Feet.	Age. Years.
4	12	3	11	7	17
3	13	25.....	7	3 ..	7
75.....	22	45.....	8	35.....	9
6	16	5	10	5	10
5	18	55.....	16	4 ..	11
8	13	45.....	15	35.....	9
55.....	15	6	12	45.....	15
4	13	3	8	35.....	11
25.....	9	35.....	9	45.....	10
4	8	6	13	35.....	9
8	16	75.....	16	6	15
5	13	4 ..	7	4	10
6	15	5	12	5	13

TABLE 20.

Age of Larger Pine Growing Within the Limits of the Upper Plains.

Height. Feet.	Age. Years.	Height. Feet.	Age. Years.	Height. Feet.	Age. Years.
15 ..	39	14	31	21	44
11 ..	21	9	22	13	33
12	29	10 ..	22	19 ..	46
14	30	16 ..	30	17	39
11	35	11	36	14	27
		13 ..	32		

From these measurements it appears that the oldest and largest trees are under fifty years of age, and that the small growth averages about ten to fifteen years.

CAUSE OF PRESENT CONDITION.

Many attempts have been made to account for the present condition of the Plains, but these explanations have not been altogether satisfactory. Some have attributed the form of the Pine to a lack of certain mineral constituents in the soil necessary to the growth of

trees. This theory, however, is disproved by chemical analyses of the soil made by the Geological Survey, which show no greater poverty than is common to the surrounding region. The theory that fire, combined with the effect of very poor top soil and a hard sub-soil, is the efficient cause, has also been advanced, and certainly fire has been a very large factor in bringing about the present condition of these areas. Sufficient emphasis, however, has not been laid on the fact that the Pine is for the most part of sprout origin, and on the causes of the prostrate form of young seedling trees.

If the Plains have been in their present condition since the country was first settled, they were probably first burned over by the Indians, who were in the habit of camping in the neighborhood, as their shell-heaps show. We know that the western forests are often burned by the Indians to-day, and there is reason to believe that many even-aged stands of Pine in the Eastern States date their origin from fires set by the Indians or by lightning. It is not unreasonable, therefore, to suppose that these high rolling plains were originally stripped of their forest cover in this way. The Pines, which probably returned by seed after the first fire, were burned over again and again, and their stumps sent up sprouts which became more and more feeble after successive fires. Many old stumps, as already pointed out, became exhausted and died after repeated sprouting. Their place was taken by seedlings, and in this way the ground remained stocked with Pine.

This does not explain, however, the prostrate form of the young seedlings and many of the older trees. This peculiarity is not confined to the Plains alone, for Pine seedlings growing on bare sand in exposed situations in the neighborhood of the Plains show the same tendency. These seedlings exhibit a remarkable similarity to the forms assumed by trees near the timber line on high mountains. It is a fair inference that the very harsh and windy situations in which they grow has an effect analogous to that of great elevation. Hence it is believed that exposure and poor soil are entirely sufficient to explain why the young trees are prostrate.

A large part of the Pine, however, is coppice growth from old stumps which have lost their vigor to a large extent, and under the unfavorable surroundings are incapable of producing anything but straggling sprouts. Furthermore, the trees, which grow very slowly on the poor soil of the Plains, are killed by fire before they have time to reach a large size.



Plate XV, Fig. 1.—Prostrate Sprouts of Pitch Pine After Fire. West Plains.



Plate XV, Fig. 2.—Prostrate Seedling of Pitch Pine from the Plains.



Plate XVI, Fig. 1.—Young Pitch Pine, Killed Back Once by Fire, Sprouting from the Stump. West Plains.



Plate XVI, Fig. 2.—Young Pitch Pine which has Sprouted After Fire. West Plains.



Plate XVII, Fig. 1.—A Sprouting Pitch Pine Repeatedly Killed Back by Fire and Dying from its Effects.





Plate XVII, Fig. 2.—Prostrate Sprouting Pitch Pine from the Plains Repeatedly Killed Back by Fire and now Nearly Dead.



Plate XVIII, Fig. 1.—Creeping Branches of Pitch Pine This Tree Died from Repeated Fires After Sprouting For a Series of Years. The Main Root was 63 Years Old. View from Above. West Plains.



Plate XVIII, Fig. 2.—Side View of Sprout in Fig. 1, Showing the Root. West Plains.

V.

SILVICULTURAL NOTES ON THE PITCH AND SHORTLEAF PINES.

OCCURRENCE.

The species of Pine most abundant in South Jersey are Pitch Pine (*Pinus rigida* Mill) and the Shortleaf Pine (*Pinus echinata* Mill). The latter is locally called Yellow Pine. In certain sections there are scattered individuals of Jersey or Scrub Pine (*P. virginiana* Mill), and on the southern extremity of Cape May the writer found a single Loblolly Pine (*P. taeda* Linn). Pitch and Shortleaf Pine are commonly found mixed together, but the latter predominates as a rule on the better soils, giving way on poorer soil to Pitch Pine. This is not because the Pitch Pine prefers poor soil, but because it is less fastidious. It flourishes not only on loamy soil, but on dry, unproductive sand, and in low, wet areas, called Pine swamps.

FORM AND DEVELOPMENT.

In dense stands both the Shortleaf and Pitch Pines have long, clear trunks and short, narrow crowns. When growing in mixture they reach about the same maximum dimensions, namely, a height of eighty-five and a diameter of two feet. The greater part of the Pitch Pine is, however, growing in open stands. In many cases it has not come from the seed, but is of sprout or coppice growth. Such trees are short, very scrubby, and often crooked. Even when growing in crowded stands the young sprouts are usually contorted.

REPRODUCTION.

Under favorable conditions both species reproduce themselves prolifically from the seed, especially on abandoned fields and old roads, and in small openings in the forest. Near Winslow there is a con-

spicuous example of an old field admirably seeded to Pitch Pine. This field lay northeast of a fifty-year old forest of Pine poles. For a distance of six or eight yards from the poles there was practically no young growth at all; from that point the ground was densely seeded, the best trees, both in height and diameter, standing about twenty yards from the seed trees; then the reproduction remained good for about ten yards, and beyond rapidly became scattered.

On the better classes of soil both trees are creeping back, among the second-growth hardwoods, to the ground they once occupied, and in the end they will probably predominate over all other species.

After fires the ground is apt to clothe itself, when there is plenty of light, with huckleberry bushes, Scrub Oaks, and dry-land moss. This soil-covering acts as a hindrance to reproduction. On the other hand, where the land is so severely burned that the bare sand is exposed, seedlings find great difficulty in maintaining themselves, although, as is shown in the discussion of the Plains, crippled specimens are found. The best conditions for reproduction seem to be where the mineral soil is exposed, and has a fair admixture of humus.

The most interesting silvicultural characteristic of the Pitch Pine is its ability to send up shoots from dormant buds at the collar of the roots and to sprout in the crown after the foliage has been completely burned. There is a prevailing impression that the sprouts from the stumps of Pitch Pine never become trees, but die within a few years. In South Jersey this is not the case, for a large proportion of the trees now found in the burned districts are, beyond question, sprouts. How long such sprouts will live it is not possible to assert, but many trees, about the origin of which there can be no doubt, were found to be forty years old. It is probable that these trees have formed strong independent roots and will live as long as seedlings, other things being equal.

The largest trees found sprouting at the stump were about eight inches in diameter. Old first-growth Pine does not sprout.

It was not possible to determine how long the sprouts in the crowns will live, but from observations in the field it seems probable that where the foliage is entirely burned the fresh sprouts will be short-lived. The oldest found were three years of age.

Shortleaf Pine possesses to a small degree the ability to sprout at the root-collar. Scattered examples of small shoots were found, but no large trees were seen which could be proved to have had this origin.

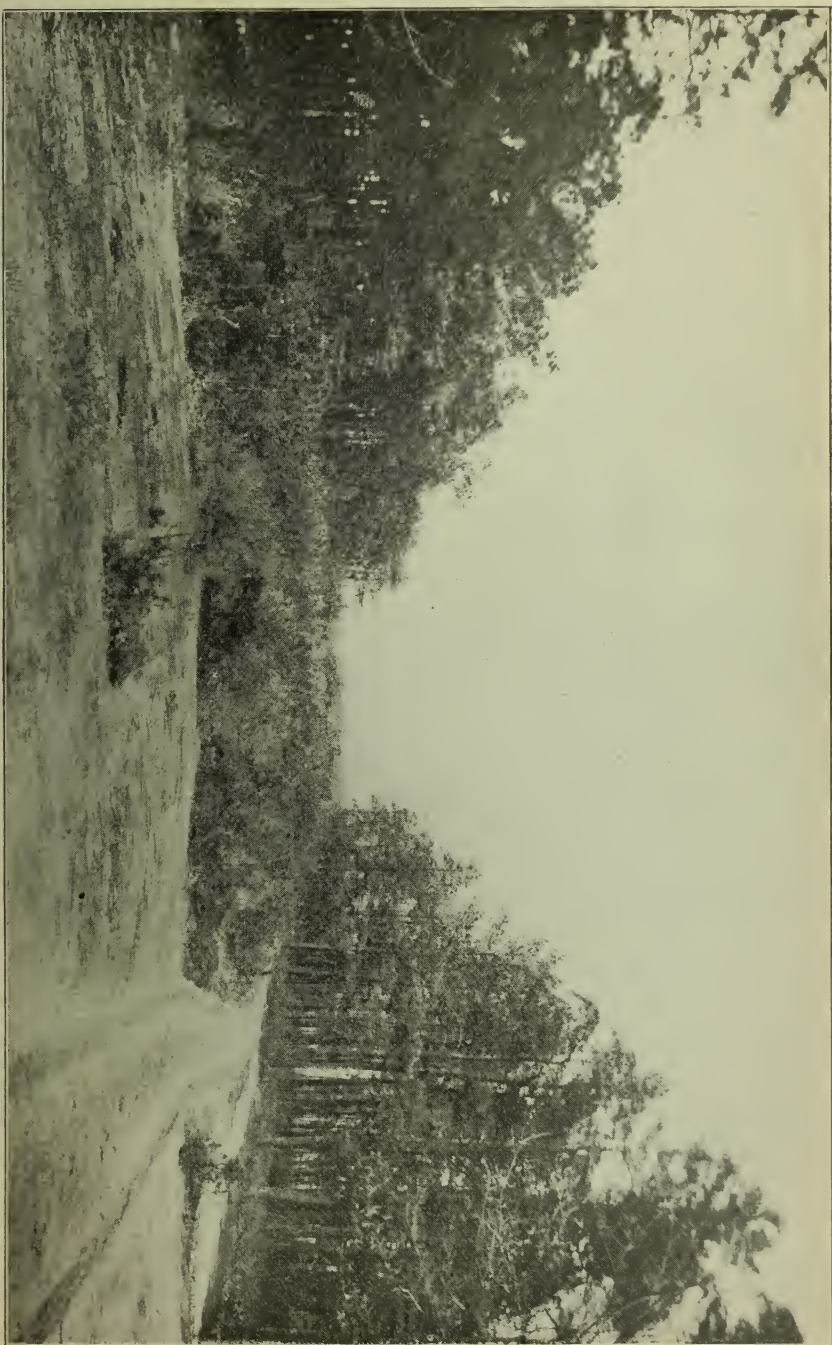


Plate XIX.—Young Pitch Pine Coming Up on an Old Road. Whiting's, N. J.

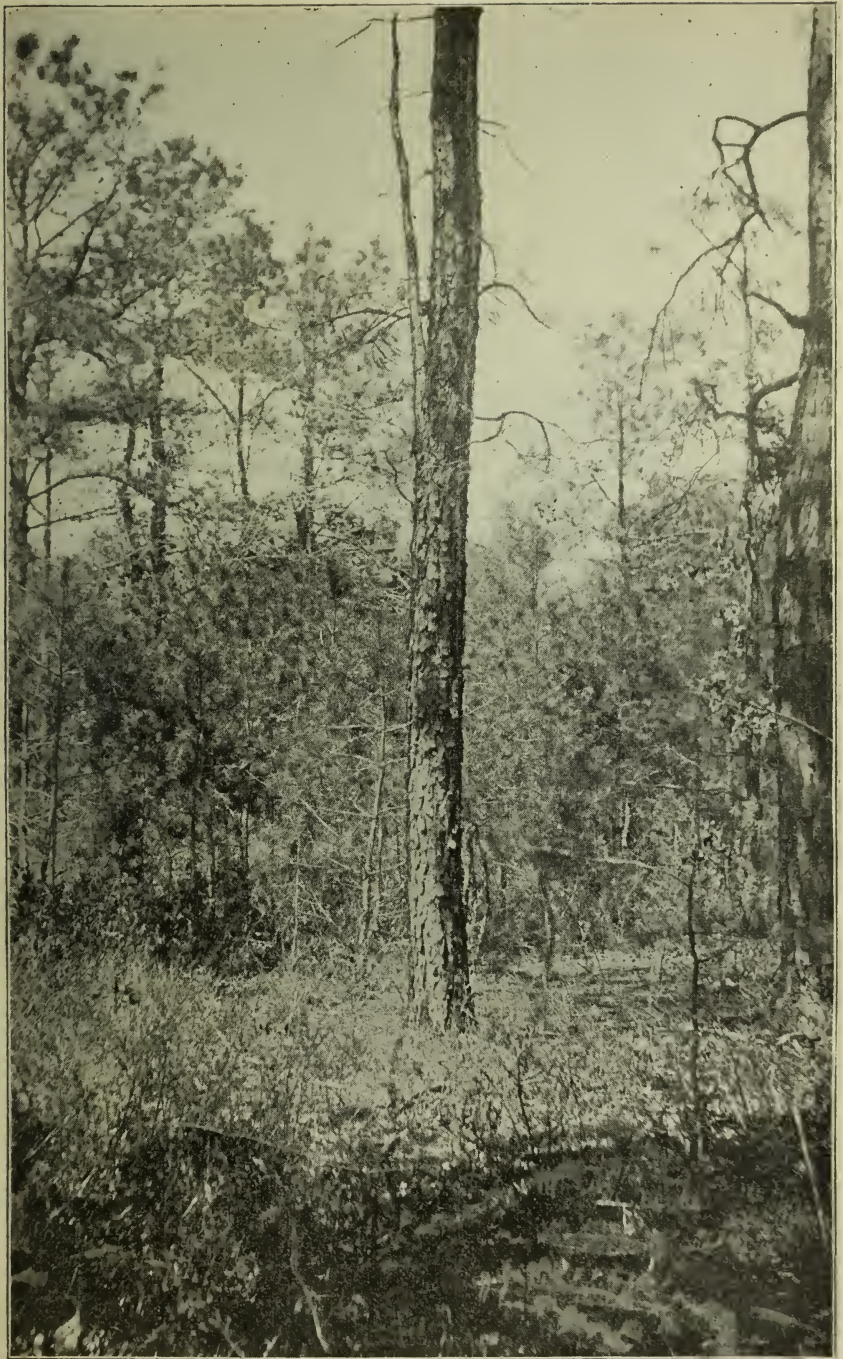


Plate XX.—Group of Young Pitch Pine in an Opening in the Forest. Whitings, N. J.

The ability of Pitch Pine to sprout is a very important characteristic, for in this way burned land is restocked at once with a growth of Pine, which, though of little value for anything but cord-wood, shades the ground and will eventually restore the seedling growth if the fires are kept out.

GROWTH.

Mention has already been made of the study in the old Pine near Winslow, and on page 29 is given a summary of the results of twelve test acres. In this forest measurements to determine the growth and contents were taken on forty trees, the results of which are summarized in the table given below. The majority of the trees were Shortleaf Pine, but three specimens of Pitch Pine were also measured. It is interesting to compare these measurements with those given for the same tree in Dr. Charles Mohr's "Timber Pines of the Southern United States." It will be seen that the average diameter of the trees over 120 years old studied in New Jersey is 16.2 inches, and that the average diameter of the trees of the same age measured by Dr. Mohr is 22.7 inches. Further, Dr. Mohr gives 120 feet as the maximum height of Shortleaf Pine, whereas the largest tree found in New Jersey was but 85 feet. It is evident that the Shortleaf Pine attains much greater dimensions and, as will be shown below, grows much more rapidly in the South than near its northern limit in New Jersey.

Although the Pitch Pine was found scattered through the forest, the trees were for the most part larger in diameter, and the growth was found to be considerably more rapid, both in height and diameter, than that of the Shortleaf Pine.

TABLE 21.

Summary of Thirty-seven Stem Analyses of Yellow Pine and Three of Pitch Pine, near Winslow, New Jersey.

Tree No.	Diameter breast high. Inches.	Age. Years.	Height. Feet.	Volume of stem, with bark. Cubic feet.	Board feet.	Current annual growth in per cent. of the total volume.
23	7.0	74	57.0	7.25	...	0.97
27	7.6	80	65.1	12.15	...	2.10
22	8.7	80	65.3	14.74	...	0.44
21	8.9	75	67.1	13.35	...	0.99
3	9.7	162	63.4	18.1	75	1.04
28	10.1	79	67.0	19.99	75	0.73
5	10.8	96	65.4	21.95	83	2.54
1	10.9	139	62.4	25.48	93	0.99
25	11.2	82	65.7	25.52	107	1.90
4	11.3	126	63.1	23.71	39	1.38
8	11.7	124	62.3	25.67	87	1.59
7	11.8	121	58.7	27.16	106	0.66
2	12.1	153	73.8	30.89	98	1.23
6	12.2	129	66.3	27.50	101	0.69
12	12.9	149	63.5	34.73	122	1.21
13	13.2	197	64.9	40.57	161	1.34
10	14.1	111	68.9	42.92	173	1.72
11	13.8	110	70.6	44.24	192	.93
9	14.4	118	72.0	46.82	178	1.40
19	14.8	191	70.6	53.56	181	0.95
17	15.9	122	75.9	60.45	217	1.60
33	15.9	...	71.2	52.53	181	...
16	16.1	126	77.0	56.76	202	1.13
34	16.1	...	76.4	68.58	260	...
39	16.2	...	75.4	63.0	278	...
32	16.3	...	67.3	56.29	202	...
40	17.0	...	71.7	61.7	204	...
29	17.3	192	75.6	72.47	358	0.76
18	17.4	166	77.4	73.52	282	0.42
14	17.5	197	85.2	80.07	408	0.62
15	17.5	159	78.0	70.73	317	1.40
31	17.6	...	76.9	75.26	337	...
35	18.4	...	77.1	89.93	438	...
36	18.6	...	64.0	70.95	226	...
30	18.8	191	72.5	77.34	358	0.87
37	20.2	...	74.7	91.18	406	...
30	22.2	...	77.4	110.85	562	...
26*	10.6	76	62.7	20.75	81	1.5
20*	12.2	79	66.5	28.92	102	1.95
24*	14.0	79	74.5	42.6	155	2.3

* Pitch Pine.

It was not the purpose of this investigation to make an exhaustive study of the growth and production of the Pine, but to gather statistics

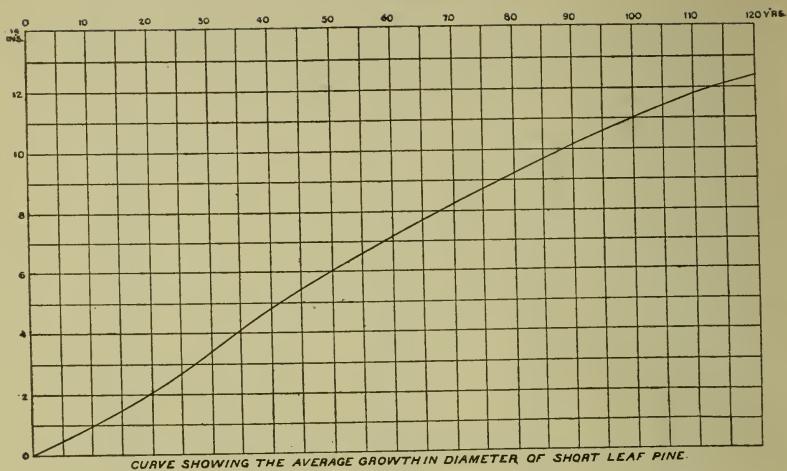


Plate XXI. Fig. 1.

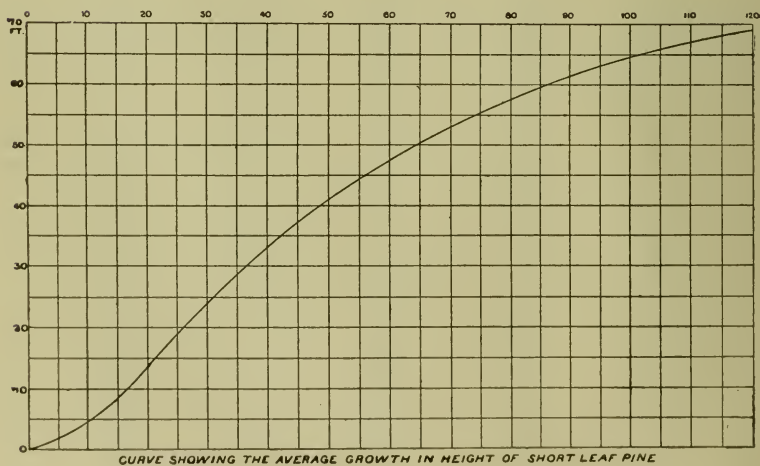


Plate XXI. Fig. 2.

chiefly for illustrative purposes and sufficient in number to give an adequate idea of what the trees are capable of producing. In order to find an average of the growth of the trees measured they were worked up together in the following way: The progress of the growth in diameter and height of each tree analyzed was plotted on cross-section paper, and a normal curve was struck through the various points. These curves represent an average of all the trees, and are shown in Plate XXI. The values taken from the curves appear in the following table:

TABLE 22.

*Average Rate of Growth of Twenty-seven Shortleaf Pines
in Diameter and Height.*

Age. Years.	Diameter. Inches.	Height. Feet.
30	3.4.....	24.0
40	4.8.....	33.0
50	6.0.....	41.0
60	7.2.....	47.5
70	8.3.....	53.0
80	9.2.....	57.5
90	10.2.....	61.5
100	11.0.....	64.5
110	11.8.....	67.0
120	12.4.....	69.0

Here again it is interesting to compare the results of our measurements with those made by Dr. Mohr in the South. It will be seen that the growth, both in height and diameter, is as different as for two distinct species. Thus Dr. Mohr gives sixty feet as the average height of trees fifty years old, whereas in New Jersey the trees at that age are between forty and forty-five feet high. At eighty years the trees reach a height of seventy-five feet in the South, but in New Jersey they average less than sixty feet. In the same way the growth in diameter of the trees measured in New Jersey is disproportionately small compared with Dr. Mohr's figures. It is evident that in New Jersey the rate of growth is very much less than in the South.

TABLE 23.

*Rate of Growth of Shortleaf Pine in the South, According to
Dr. Charles Mohr.*

Age. Years.	Diameter. Inches.	Height. Feet.
30	7.4.....	41
40	9.3.....	51
50	11.0	60
60	12.7	67
70	14.5.....	71
80	16.0	75
90	16.5.....	78
100	17.0.....	81

It is also interesting to compare these figures with what the Scotch Pine is capable of doing in normal stands in Germany. Dr. Wilhelm Weise gives as the height and diameter of average trees in normal stands of Scotch Pine the following figures :

TABLE 24.

*Average Diameter and Height of Scotch Pine at Different Ages on Medium
Soil, According to Dr. Wilhelm Weise.*

Age Years.	Diameter. Inches.	Height. Feet.
30.....	2.8.....	25.6
40.....	4.3.....	34.8
50.....	5.8.....	43.0
60.....	7.1.....	50.5
70.....	8.3.....	57.1
80.....	9.4.....	62.7
90.....	10.3.....	66.9
100.....	11.1.....	70.5
110.....	11.8.....	73.1
120.....	12.3.....	75.4

It is exceedingly interesting to note how closely these agree with the results of the stem analyses made near Winslow. These figures from Weise are for stands of the third or medium class of soil, to which the locality at Winslow would approximately correspond.

There was only a small number of Pitch Pine cut at Winslow by the lumbermen, so that, compared with the Shortleaf Pine, the meas-

urements are few. The average growth in height of these trees was, however, determined, and is given in the following table :

TABLE 25.

Age. Years.	Height. Feet.
20	16
30	33
40	45
50	53.5
60	59.5
70	63.5
80	67

These trees belong to the dominant class of trees in their stand, but as the majority of the Pitch Pines were dominant they represent fairly all the trees of the group. The diameter growth also is apparently more rapid than that of the Shortleaf Pine, but it is not given here because of the small number of measurements.

The rate of growth of Pine sprouts is very much less than that of seedling trees. A curve has been drawn showing the height growth of an average Pine shoot where the land has not been burned and there is a good layer of humus. The values from this curve are as follows :

TABLE 26.

Growth in Height of Pine Sprouts.

Age. Years.	Height. Feet.
20	12
30	20
40	25

Coppice which has been burned again and again, like that on the Plains, grows much more slowly, as may be seen from the figures on pages 41 and 42.

The rate of growth in volume was determined for thirty trees of Shortleaf Pine and the results are given in percentage of the whole volume in the table on page 48. The average rate of growth for trees over one hundred years old is 1.1 per cent. per annum of the whole volume of the trees ; of trees about eighty years old, 1.5 per cent., and of Pitch Pine of eighty years old, 1.9 per cent.

YIELD.

The development of the individual tree is interesting and important, but still more so is the amount of timber which can be produced on a given area in a given time. It is unfortunately true that the second-growth forest in many parts of South Jersey is on a rapid decline, and is producing less and poorer timber with each generation. For comparison it is desirable to obtain a definite idea of what can be produced under favorable circumstances when the forest is protected from fire. In New Jersey data from which to gather these figures are difficult to find, for the system of cutting has been so loose and so entirely without regard to reproduction that the second-growth forests are, as a rule, irregular and incomplete. Several plots, however, were found where an old field has been densely seeded to young Pine. Mention has already been made of the second-growth stand studied at Winslow. The forest now in question is growing on rather dry, loamy sand, a soil somewhat superior to the average forest land. The ground is covered with a good matting of humus and a thick layer of leaf litter, and there is but little undergrowth. The forest is practically fully stocked, and is composed for the most part of Shortleaf Pine, with about ten per cent. of Pitch Pine. Two acres were surveyed and are given in detail below.

TABLE 27.

One Acre of 80-year-old Second-Growth Pine at Winslow, New Jersey.

Diameter breast high. Inches.	Pine.	Oak.	Holly.
2 .....	..	86 .....	..
3	2	9	1
4	2	4	1
5	9 .....	..	..
6	38 .....	..	..
7	61 .....	..	..
8	54 .....	..	..
9	47 .....	..	..
10	39 .....	..	..
11	16 .....	..	..
12	13 .....	..	..
13	2 .....	..	..
14	1 .....	..	..
15	1 .....	..	..
16	1 .....	..	..
	<hr/> 286	<hr/> 99	<hr/> 2

Average height—65 feet.
 Average diameter over six inches—8.6 inches.
 Average age—80 years.
 Total volume over six inches without branches—4,339 cubic feet.
 Merchantable contents over ten inches—7,397 board feet; over six inches—15,978 board feet.
 Density—1.0.
 Soil—rather dry, loamy sand.
 Humus and litter deep.

TABLE 28.

One Acre of 80-year-old Second-Growth Pine at Winslow, New Jersey.

Diameter breast high. Inches.	Pine.	Oak.	Holly.
1 .....	...	42	4
2.....	2	56	2
3.....	4	29	4
4.....	5	12	2
5.....	25	5 .....	...
6.....	49 .....	...	...
7.....	64 .....	...	...
8.....	53 .....	...	...
9	40 .....	...	...
10.....	28 .....	...	...
11.....	24 .....	...	...
12.....	13 .....	...	...
13.....	11 .....	...	...
14.....	3 .....	...	...
15.....	2 .....	...	...
	323	144	12

Average height—65 feet.
 Average diameter over six inches—8.9 inches.
 Average age—80 years.
 Total volume over six inches without branches—4,483 cubic feet.
 Merchantable contents over ten inches—7,604 board feet; over six inches—16,993 board feet.
 Density—1.0.
 Soil—Rather dry, loamy sand.
 Humus and litter deep.

It will be seen that these two acres contain about three hundred trees each, yielding in merchantable timber over seven thousand board feet for trees ten inches and over in diameter, and for trees over six inches about sixteen thousand board feet each. The age is about eighty years on the stump, the average height about sixty-five

feet, and the average diameter nearly nine inches for trees above six inches. It appears that as large a yield per acre for trees over ten inches has been obtained from these acres as from the acres studied in the original forest where the trees were about twice as old, and that the yield in cubic feet for trees over six inches in diameter is fully twice as great. About one-quarter of the trees on these two acres were being cut for pilings and logs. The remaining small trees were left to reach a larger size. It will also be seen that the average height on these acres is greater than that given in our table of heights in the first part of the chapter. This is explained by the fact that the soil is considerably better than that in which the majority of the trees measured were growing.

Another plot of nearly pure seedling Pine was found near Brown's Mills, in which the trees were about thirty feet in height and had an estimated age of about forty years. One-quarter of an acre was surveyed in this forest. It was not quite fully stocked. If we call the density of a complete stand 1.0, this one-quarter acre would have a density of 0.9. From the valuation survey it may be seen that there are 272 trees on the one-quarter acre, which would make 1,088 trees per acre, or if the plot were fully stocked, 1,210 trees per acre. The average diameter is 4.4 inches.

TABLE 29.

*One-quarter Acre Measured in Second-Growth Shortleaf Pine, near
Brown's Mills, New Jersey.*

Diameter Breast high.	Pine.
1 Inches.....	2
2 "	18
3 "	68
4 "	101
5 "	49
6 "	24
7 "	9
8 "	1
	<hr/> 272

Soil—white sand.

Humus—good.

Density—0.9.

Estimated height—30 feet.

Estimated age—about 40 years.

It is interesting to compare these figures with those given for the Scotch Pine by Weise for full-stocked stands in Germany. The following table shows that at eighty years a fully-stocked stand growing on medium soil contains 313 trees, yielding 4,258 cubic feet per acre, and that the number of trees at forty years is 1,222. These figures are so close to those given above that the table may be used in a general way as a guide to what may be produced in normal stands in our own Pine in New Jersey.

TABLE 30.

Volume in Cubic Feet and the Number of Trees Per Acre of Scotch Pine at Different Ages on Medium Soil, according to Dr. Wilhelm Weise.

Age. Years.	No. of trees.	Volume in cubic feet. Measurements taken down to 2 3 inches.
30	2505	828.8
40	1222	1972.0
50	745	2700.8
60	510	3301.0
70	388	3815.4
80	313	4258.4
90	263	4615.7
100	227	4901.5
110	212	5144.4
120	186	5330.2

In conclusion we may say that, at 80 years of age, a portion of the trees will be large enough for sawlogs and piling, but that for large timber, 120 to 150 years will be required. For the production of firewood 40 to 50 years will suffice.



Plate XXII.—White Cedar Swamp, Ocean County, N. J.

VI.

SILVICULTURAL NOTES ON THE WHITE CEDAR

FORM AND DEVELOPMENT.

White Cedar grows in very dense stands and has in consequence a short, narrow crown and a long, clear, straight bole. Small pin branches are often scattered over the stem, but they do not seriously affect the quality of the wood. The length of the green crown is as a rule one-fourth to one-third the total length of the tree. The oldest timber studied was about eighty years old, at which age it attains a maximum diameter of fifteen inches and a height of seventy feet. One very old unsound specimen was measured which had a diameter of thirty inches at breast-height and was about seventy feet high. In early youth a tap-root is developed, but in later life the tree has a flat root system, with strong superficial lateral roots.

SITUATION AND SOIL.

The White Cedar is fastidious. It is strictly a swamp tree, and the boundaries of its distribution usually coincide exactly with the edges of swamps, although a few short and scrubby stragglers are found on dry ground. In some cases where a Cedar swamp runs into a Pine swamp the Cedar mingles with the Pine and finally runs out where the ground is too dry for it to grow.

Cedar swamps are often classified as wet and dry. In the former there is standing water, a very large amount of sphagnum moss and usually little or no Pine. As a rule the timber is less dense, and it is said to attain smaller dimensions and to be poorer in quality than that growing in dry swamps. In both cases there is a mud bottom, but in dry swamps interlacing Cedar roots cover it with a complete

crust. The drier the swamp the greater the proportion of Pitch Pine. A hard-bottom swamp is one in which the trees rest on gravel. It is said that in such situations the trees are apt to be shaky.

REPRODUCTION.

After the young trees grow large enough for the crowns to meet and form a continuous canopy, no new seedlings spring up. A certain amount of light is required for the germination of the seed. The trees are, however, able to bear very considerable shade, both from above and from the side. This is shown by the very long life of suppressed trees and by the extremely crowded character of the woods. When a Cedar forest is cut, young seedlings spring up in great abundance within two or three years. There is as a rule a more complete reproduction in dry than wet swamps, chiefly on account of the amount of standing water in the latter. It has been observed that on badly-burned areas, as a rule, no seedlings spring up for a long time, even though there are seed trees close at hand. From this we must conclude either that the seed from which the usual reproduction springs lies dormant in the soil, waiting to germinate as soon as there is sufficient light, or that the burning of the sphagnum makes an inhospitable bed for the germination of the seed. To show how many young plants come up on a well-seeded area, two small plots were marked off, one of twelve square feet, where the ground was completely seeded, and the other of one hundred square feet, where there were five old stumps and the reproduction was not so thick. On the first plot were found 968 plants, which would make 3,513,840 young trees per acre. On the other plot there were 3,200 plants, equivalent to 1,393,920 per acre.

The youngest tree found to be bearing seed was thirteen years old.

GROWTH.

In view of the value of Cedar, it is important to have some definite figures concerning its rate of growth and its reproductive capacity. On account of the regular growth of the trees and the comparatively even stands, a few measurements will suffice to afford a basis for broad generalization. During lumbering operations at Job's swamp, near Whitings, and at Marigold swamp, near New Gretna, eighteen

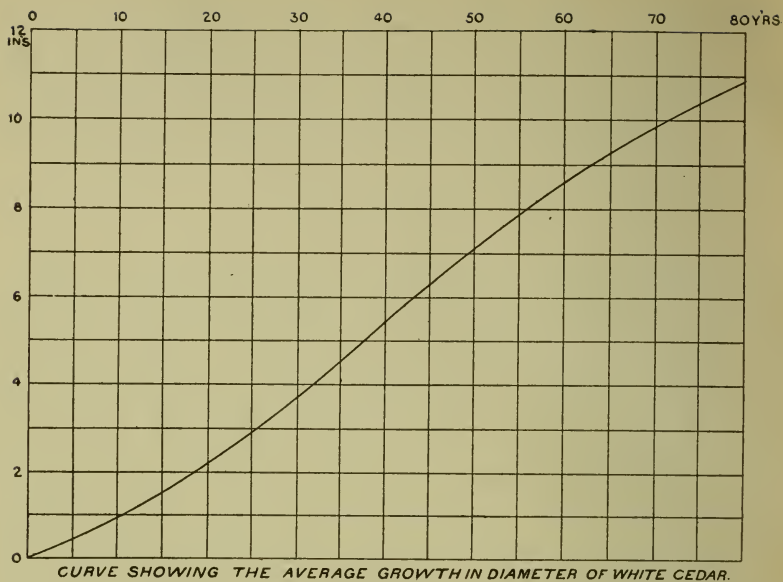


Plate XXIII. Fig. 1.

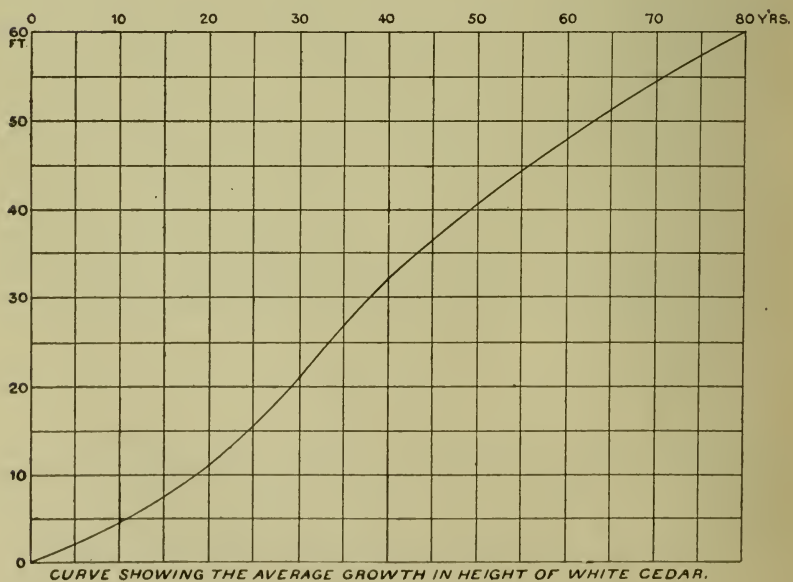


Plate XXIII. Fig. 2.

trees were carefully analyzed. These measurements are summarized below.

TABLE 31.

Summary of Nineteen Stem Analyses of White Cedar, taken at Job's Swamp, Burlington County, and Marigold Swamp, Ocean County.

Tree No.	Diameter breast high, inches.	Height of stump, Feet.	Age, Years.	Height, Feet.	Total volume, Cubic feet.	Merch. volume, Cubic feet.	Merch. volume, Board feet.	No. of Rails.	Current annual growth, Per cent. of whole volume.	LOCALITY.
13	2.3	0.5	39	24.6	0.41	.....	.....	.....	.....	Job's Swamp.
12	3.9	1.0	49	40.1	1.88	.....	.....	.....	.....	Job's Swamp.
9	5.8	1.0	79	58.7	5.6	5.2	13	2	.....	Job's Swamp.
17	6.1	0.7	66	56.7	6.0	5.2	13	2	.....	Marigold Swamp.
16	6.6	0.6	65	57.2	7.8	6.5	23	1	.....	Marigold Swamp.
8	6.6	0.7	79	58.0	7.1	6.7	18	2	1.3	Job's Swamp.
15	7.1	0.8	66	55.6	8.1	7.0	23	1	1.5	Marigold Swamp.
3	7.4	0.8	77	58.2	8.7	8.3	23	2	1.8	Job's Swamp.
14	8.1	0.7	66	58.3	12.5	11.7	32	2	2.8	Marigold Swamp.
4	8.3	0.9	75	61.0	11.0	10.2	28	2	2.2	Job's Swamp.
5	8.6	1.1	77	62.5	12.6	11.8	41	1	2.0	Job's Swamp.
18	8.7	0.8	66	64.2	13.8	13.1	37	2	.....	Marigold Swamp.
1	9.0	0.7	77	60.1	12.7	12.0	44	1	2.0	Job's Swamp.
2	9.1	0.6	75	57.7	14.1	13.5	50	1	3.0	Job's Swamp.
11	9.4	0.7	80	59.8	12.9	12.3	41	0	2.8	Job's Swamp.
10	10.5	1.2	79	61.6	19.0	17.6	71	0	1.6	Job's Swamp.
7	10.8	1.0	79	58.8	18.6	17.6	62	1	2.2	Job's Swamp.
6	11.2	1.1	79	63.9	21.6	20.3	67	1	1.7	Job's Swamp.

The rate of growth in diameter and height was obtained in the same way as that of the pine, by plotting the progress of the growth of each tree on cross-section paper and drawing a normal curve through the various points. The values from these average curves are as follows:

TABLE 32.

Average Rate of Growth in Diameter and Height of Seventeen White Cedars.

Age, Years.	Diameter, Inches.	Height, Feet.
20	2.2	11
30	3.7	21
40	5.4	32
50	7.1	40.5
60	8.6	48
70	9.8	54.5
80	10.9	60

The Cedar appears, from this table, to require on an average sixty years to reach a height of fifty feet and eighty years to reach sixty. It is interesting to note that when the forest is thinned the trees grow more rapidly in diameter than when they remain in crowded stands. At Marigold swamp seven stumps were measured of trees which had stood for some years on the edge of a clearing. These trees were growing at the rate of 2.2 inches in diameter in ten years, whereas four trees measured within the same stand showed an average rate of growth of about 1.05 inches in ten years, or a little less than half.

YIELD.

There are few trees, if any, which grow in as dense masses as White Cedar. In order to show the number of trees per acre and the amount of wood at different ages, eight sample plots were measured and the trees counted. These valuation surveys are summarized below. At twenty years of age there were over 10,000 trees per acre, at forty years about 3,500, and at eighty years in one case still over 1,000. Special attention is directed to Plots Nos. 51 and 52. These plots were within a few hundred yards of each other and of about the same age and height. In the first case, however, there are nearly two hundred trees less and a correspondingly larger diameter. While the number of cubic feet per acre is nearly the same the number of board feet is very much larger in the first plot, although there is a smaller number of trees. Plot No. 54 is of about the same age as Plot No. 52, but has only one-half as many trees. These two plots were also very near together, the former on the edge of a swamp. A number of stumps of nearly as large diameter as the trees within the stand were counted and the age found to be the same as in Plot No. 52. In Plot No. 54 there were over 1,000 more cubic feet and over 10,000 more board feet per acre, though the number of trees was only about one-half as great. From these figures it follows: First, that it requires about sixty years to produce lumber in paying quantities; second, that it would pay to thin the forest when it is about forty to sixty years old.

TABLE 33.

Summary of Sample Areas Surveyed in Job's Swamp, near Whitings, and Marigold Swamp, near Tuckerton, New Jersey.

Plot Number.	Area.	Number of cedar two inches and over.	Number of cedar under two inches.	Average diameter breast high.	Average diameter breast high.	Average height.	Average age. Years.	PER ACRE.				
								Number of trees two inches and over.	Number of trees under two inches	Board feet.	Cubic feet.	Rails.
	Sq. ft.			Inch's	Inch's	Feet.						
57	400	107	.....	03	3	20	21	11,663	.....	.....	.....	.....
58	2,500	199	116	23	7	35	39	3,463	2,018	.....	1,420	3,689
	Acres.											
55	0.25	472	2	4.6	8	42	49	1,888	8	.....	5,286	2,676
53	0.25	326	5	5.4	11	48 5	62	1,304	20	9,756	5,868	2,420
51	0.25	214	0	7.2	13	60	66	856	.....	18,244	7,448	1,416
50	0.25	253	0	6.6	13	60	66	1,012	.....	14,636	7,698	1,568
54	0.25	140	0	9.2	15	65	80	560	.....	25,668	8,910	692
52	0.25	263	0	6.9	12	60	79	1,052	.....	15,596	7,624	1,472

APPENDIX.

The following results of the measurements of 55 sample plots in various portions of South Jersey are added for their value in confirming and illustrating the conclusions given in the text, and because students of the forest in this region will find an examination of them to be helpful. So also will practical men interested in the productive capacity of South Jersey, and in the effect upon it of forest fires.

One Acre of Old Pine Near Winslow, New Jersey.

Diameter breast high.	Shortleaf Pine.	Pine Stumps.	White Oak.	Black Oak.	Chestnut Oak.	Hickory.
3 Inches.....	1	...	3	6	5	1
4 " .....	...	...	1	20	8	2
5 " .....	...	1	...	27	2	1
6 " .....	...	...	...	26	5	...
7 "	1	1	...	10	2	...
8 "	3	...	...	4	2	...
9 "	3	...	...	4	1	...
10 "	5	1	1	1	...	...
11 "	6	2	1	2	1	...
12 "	2	3	...	...	...	...
13 "	3	3	...	...	...	...
14 "	3	5	...	...	...	...
15 "	8	1	...	...	...	...
16 "	6	...	...	...	...	...
17 "	4	...	...	...	...	...
18 "	1	...	1	...	...	...
19 "	3	...	2	...	...	...
20 "	1	...	...	...	...	...
21 "	1	...	...	...	...	...
22 "	1	...	1	...	...	...
Total.....	52	17	10	100	26	4

Average height of Pine—69 feet.

Diameter of average Pine over six inches—13.9 inches.

Diameter of average Pine over ten inches—14.5 inches.

Total volume of Pine over six inches—2,882 cubic feet.

Merch. volume of Pine over ten inches—9,939 board feet.

Volume of Pine under six inches—.02 cords (est.).

Average diameter of hardwoods—5.9 inches.

Volume of hardwoods—6.5 cords (est.).

Soil—dry sand.

Humus—rather poor.

Density—0.7.

The Pine stumps have been reckoned as trees in the computation of volume

One Acre of Old Pine Near Winslow, New Jersey.

Diameter breast high.	Shortleaf Pine.	Pine Stumps.	White Oak.	Black Oak.	Chestnut Oak.	Hickory.
3 Inches.....	1	...	4	1	1	5
4 "	2	...	3	11	6	...
5 "	2	...	4	18	4	...
6 "	2	...	1	10	1	...
7 "	2	...	...	7	...	...
8 "	4	...	1	3	2	...
9 "	6	...	1	2	1	...
10 "	5	...	1	1	...	...
11 "	1	...	2	...	...	...
12 " .....	...	1	1	...	...	...
13 "	6	...	...	...	...	...
14 "	7	...	...	...	...	...
15 "	13	1	1	...	...	...
16 "	4	...	...	...	...	...
17 "	6	...	2	...	...	...
18 "	4	...	...	...	...	...
21 " .....	...	...	1	...	...	...
26 " .....	...	...	1	...	...	...
	—	—	—	—	—	—
Total,	65	2	23	53	15	5

Average height of Pine—69 feet.

Diameter of average Pine over six inches—14.0 inches.

Diameter of average Pine over ten inches—15.2 inches.

Total volume of Pine over six inches—2,685 cubic feet.

Merch. volume of Pine over ten inches—8,894 board feet.

Volume of Pine under six inches—0.25 cords (est.).

Average diameter of hardwoods—6.2 inches.

Volume of hardwoods—5.0 cords (est.).

Soil—dry sand. Flat.

Humus—rather poor.

Density—0.6.

One Acre of Old Pine Near Winslow, New Jersey.

Diameter breast high.	Shortleaf Pine.	Pitch Pine.	Pine Stumps.	White Oak.	Black Oak.	Chestnut Oak.	Hickory.
3 Inches.....	...	...	...	8	7	14	2
4 ".....	...	1	...	3	16	14	...
5 ".....	5	...	...	3	14	8	...
6 ".....	3	...	...	1	10	7	1
7 ".....	4	...	...	1	1	6	...
8 ".....	4	1	...	...	...	...	...
9 ".....	4	...	...	...	2	3	...
10 ".....	4	...	...	1	...	3	...
11 ".....	1	...	2	...	...	2	...
12 ".....	3	...	4	3	...	...	...
13 ".....	4	...	1	1	...	...	...
14 ".....	11	...	2	1	...	3	...
15 ".....	9	...	2	...	...	...	...
16 ".....	8	...	1	1	1	...	...
18 ".....	4	...	...	...	...	...	...
Total.....	64	2	12	23	51	60	3

Average height of Pine—67 feet.

Diameter of average Pine over six inches—13.0 inches.

Diameter of average Pine over ten inches—14.8 inches.

Total volume of Pine over six inches—2,812 cubic feet.

Merch. volume of Pine over ten inches—8,940 board feet.

Volume of Pine under six inches—0.15 cords (est.).

Average diameter of hardwoods—5.6 inches.

Volume of hardwoods—5.5 cords (est.).

Soil—dry sand. Flat.

Humus—rather poor.

Density—0.6.

The Pine stumps have been reckoned as trees in the computation of volume.

One Acre of Old Pine Near Winslow, New Jersey.

Diameter breast high.	Shortleaf Pine.	Pine Stumps.	White Oak.	Black Oak.	Chestnut Oak.
3 Inches.....	5	...	11	14	2
4 "	5	...	4	38	...
5 "	2	...	1	28	...
6 "	5	...	...	23	1
7 "	3	...	1	12	1
8 "	5	...	1	3	2
9 "	5	...	...	2	...
10 "	6	2	...	1	...
11 "	4	2	3	...	3
12 "	2	5	...	...	...
13 "	4	3	...	...	...
14 "	1	4	4	...	...
15 "	6	2	...	...	...
16 "	6	...	1	...	...
17 "	5	2	1	...	...
18 " .....	...	...	1	...	...
19 "	1	...	...	...	...
20 "	1	...	3	...	...
Total	66	20	31	121	9

Average height of Pine—70 feet.

Diameter of average Pine over six inches—12.7 inches.

Diameter of average Pine over ten inches—13.9 inches.

Total volume of Pine over six inches—2,548 cubic feet.

Merch. volume of Pine over ten inches—8,828 board feet.

Volume of Pine under six inches—0.3 cords (est.).

Average diameter of hardwoods—5.9 inches.

Volume of hardwoods—7.5 cords (est.).

Soil—dry sand. Flat.

Humus—rather poor.

Density—0.7.

The Pine stumps have been reckoned as trees in the computation of volume.

*One Acre of Old Pine, Mixed with Young Oak, Near New Lisbon,
Burlington County, New Jersey.*

Diameter breast high.	Pitch Pine.	Pine Stumps.	White Oak.	Black Oak.	Chestnut Oak.	Post Oak.
1 Inch.....	...	...	14	3	...	...
2 Inches.....	7	...	22	17	...	1
3 ".....	9	...	16	14	...	1
4 ".....	8	...	4	4	...	2
5 ".....	9	1	5	2	...	2
6 ".....	11	3	7	3	...	1
7 ".....	5	...	4	...	1	...
8 ".....	3	1	2	...	...	...
9 ".....	16	...	1	...	...	...
10 ".....	14	...	...	1	...	...
11 ".....	4	5	2	...	...	...
12 ".....	11	2	...	...	...	...
13 ".....	7	...	1	...	...	...
14 ".....	3	...	...	...	...	...
15 ".....	3	...	...	...	...	...
16 ".....	...	1	...	...	...	...
17 ".....	3	1	...	...	...	...
18 ".....	...	1	...	...	...	...
22 ".....	...	1	...	...	...	...
Total.....	113	16	78	44	1	7

Average height of Pine—60-70 feet.

Diameter of average Pine over six inches—10.0 inches.

Diameter of average Pine over ten inches—15.1 inches.

Diameter of average Pine under ten inches—4.9 inches.

Volume of Pine over ten inches—8,000 board feet.

Volume of Pine under ten inches—3.6 cords (est.).

Average diameter of hardwoods—3.0 inches.

Volume of hardwoods—1 cord (est.).

Soil—dry white sand. Flat.

Ground burned over annually.

Density—0.6.

One Acre of Old Pine Near Winslow, New Jersey.

Diameter breast high.	Shortleaf Pine.	Pine Stumps.	White Oak.	Black Oak.	Chestnut Oak.
3 Inches.....	• ...	...	1	3	10
4 "	7	...	2	9	23
5 "	7	...	3	18	12
6 "	1	...	...	22	11
7 "	10	...	...	12	8
8 "	7	...	1	2	5
9 "	5	...	...	8	4
10 "	9	...	...	1	3
11 "	3	...	...	1	4
12 "	4	3	...	...	1
13 "	8	8	2	...	...
14 "	4	3	4	...	...
15 "	4	...	7	...	...
16 "	2	...	1	...	...
17 "	4	...	1	...	...
18 "	3	...	..	...	...
19 " .....	...	...	1	...	1
20 " .....	...	...	1	...	...
22 " .....	...	...	...	...	1
	—	—	—	—	—
Total.....	78	14	24	76	83

Average height of Pine—68 feet.

Diameter of average Pine over six inches—12.0 inches.

Diameter of average Pine over ten inches—13.4 inches.

Total volume of Pine over six inches—2,557 cubic feet.

Merch. volume of Pine over ten inches—7,739 board feet.

Volume of Pine under six inches—0.4 cords (est.).

Average diameter of hardwoods—6.9 inches.

Volume of hardwoods—13.5 cords (est.).

Soil—dry sand. Flat.

Undergrowth composed of a few Pine seedlings, small Oaks, and *Vaccinium*.

Humus—rather poor.

Density—0.6.

One Acre of Old Pine Near Winslow, New Jersey.

Diameter breast high.	Shortleaf Pine.	Pitch Pine.	Pine Stumps.	White Oak.	Black Oak.	Chestnut Oak.
3 Inches.....	...	...	...	7	1	4
4 " .....	...	...	...	9	6	10
5 "	5	...	...	8	5	7
6 "	2	...	...	5	2	6
7 "	5	...	...	3	4	6
8 "	3	...	...	2	2	5
9 "	4	...	...	2	2	7
10 "	4	1	1	...	...	2
11 "	6	...	...	...	1	1
12 "	2	...	1	...	...	3
13 "	4	...	1	2	...	...
14 "	6	...	...	1	...	2
15 "	2	...	...	1	...	...
16 "	10	...	...	...	...	1
17 "	3	1	...	1	...	...
18 "	3	...	...	1	...	...
19 " .....	...	...	...	...	...	...
20 " .....	...	...	..	2	...	...
21 "	1	...	...	...	...	...
Total.....	60	2	3	44	23	54

Average height of Pine—68 feet.

Diameter of average Pine over six inches—13.0 inches.

Diameter of average Pine over ten inches—14.3 inches.

Total volume of Pine over six inches—2,228 cubic feet.

Merch. volume of Pine over ten inches—7,521 board feet.

Volume of Pine under six inches—0.15 cords (est.).

Average diameter of hardwoods—6.8 inches.

Volume of hardwoods—8.5 cords (est.).

Soil—dry sand. Flat.

Humus—rather poor.

Density—0.6.

The Pine stumps have been reckoned as trees in the computation of volume.

One Acre of Old Pine Near Winslow, New Jersey.

Diameter breast high.	Shortleaf Pine.	Pine Stumps.	White Oak.	Black Oak.	Chestnut Oak.	Hickory.
3 Inches.....	1	...	6	8	1	1
4 " .....	...	...	2	9	1	1
5 "	1	...	4	11	2	...
6 "	4	...	1	15	3	...
7 "	4	...	4	12	2	...
8 "	3	...	1	6	3	...
9 "	4	...	...	4	3	...
10 "	9	2	1	2	1	...
11 "	4	...	...	...	3	...
12 "	2	3	...	...	4	...
13 "	3	4	1	...	...	...
14 "	5	3	1	...	1	...
15 "	8	5	...	...	1	...
16 "	1	1	1	...	...	...
17 "	2	...	...	1	...	...
18 " .....	...	...	2	...	1	...
19 "	2	...	...	...	...	...
Total.....	53	18	24	68	26	2

Average height of Pine—66 feet.

Diameter of average Pine over six inches—12.4 inches.

Diameter of average Pine over ten inches—13.5 inches.

Total volume of Pine over six inches—2,388 cubic feet.

Merch. volume of Pine over ten inches—7,488 board feet.

Volume of Pine under six inches—.04 cords (est.).

Average diameter of hardwoods—7.0 inches.

Volume of hardwoods—9.5 cords (est.).

Soil—dry sand. Flat.

Humus—rather poor.

Density—0.6,

The Pine stumps have been reckoned as trees in the computation of volume.

One Acre of Old Pine Near Winslow, New Jersey.

Diameter breast high.	Shortleaf Pine.	Pine Stumps.	White Oak.	Black Oak.	Chestnut Oak.	Post Oak.	Hickory.
3 Inches.....	1	...	26	7	...	...	2
4 "	2	...	12	14	4	...	...
5 "	2	...	10	15	2	...	...
6 "	2	...	8	21	2	...	1
7 "	6	...	4	12	1
8 "	2	...	6	3	1
9 "	4	...	6	1	1
10 "	4	...	4	1	2	1	...
11 "	2	2	...	1	2
12 "	10	4	1
13 "	5	...	1
14 "	8	...	1
15 "	5	1
16 "	2
17 "	6
19 "	1
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Total.....	62	6	79	75	15	1	4

Average height of Pine—68 feet.

Diameter of average Pine over six inches—12.2 inches.

Diameter of average Pine over ten inches—13.7 inches.

Total volume of Pine over six inches—2,127 cubic feet.

Merch. volume of Pine over ten inches—7,208 board feet.

Volume of Pine under six inches—0.7 cords (est.).

Average diameter of hardwoods—5.7 inches.

Volume of hardwoods—7.0 cords (est.).

Soil—dry sand. Flat.

Undergrowth composed of young Oaks and a few Pine seedlings.

Humus—rather poor.

Density—0.6.

The Pine stumps have been reckoned as trees in the computation of volume.

One Acre of Old Pine Near Winslow, New Jersey.

Diameter breast high.	Shortleaf Pine.	Pine Stumps.	White Oak.	Black Oak.	Chestnut Oak.	Hickory.
3 Inches.....	14	...	6	8	1	5
4 "	8	...	10	15	...	...
5 "	4	...	2	20	3	...
6 "	3	...	2	16	2	..
7 "	7	...	...	6	...	...
8 "	9	...	...	5	3	1
9 "	8	...	1	1	1	...
10 "	9	...	...	1	...	...
11 "	5	5	...	1	1	...
12 "	1	8	1	...	...	...
13 "	1	10	1	...	...	...
14 "	6	1	...	...	...	...
15 "	3	...	2	...	...	...
16 "	1	...	1	...	...	...
17 "	2	...	4	...	...	...
18 " .....	...	...	...	...	...	...
19 " .....	...	...	2	...	...	...
20 " .....	...	...	1	...	...	...
21 " .....	...	...	1	...	...	...
Total.....	81	24	34	73	11	6

Average height of Pine—68 feet.

Diameter of average Pine over six inches—11.2 inches.

Diameter of average Pine over ten inches—12. 6 inches.

Total volume of Pine over six inches—2,048 cubic feet.

Merch. volume of Pine over ten inches—6,134 board feet.

Volume of Pine under six inches—06 cords (est.)

Average diameter of hardwoods—6.4 inches.

Volume of hardwoods—7.5 cords (est)

Soil—dry sand. Flat.

Humus—rather poor.

Density—0.7.

The Pine stumps have been reckoned as trees in the computation of volume.

*One Acre of Old Pine, Mixed With Young Oak, Near New Lisbon,
Burlington County, New Jersey.*

Diameter breast high.	Shortleaf Pine.	Pine Stumps.	Black Oak.	White Oak.	Chestnut Oak.	Post Oak.
1 Inch.....	...	...	...	9	2	6
2 Inches.....	1	...	10	25	1	10
3 "	6	1	31	8	4	6
4 "	4	...	20	20	6	7
5 "	8	...	9	12	2	2
6 "	4	3	12	6	2	1
7 "	6	...	4	4	1	1
8 "	5	4	...	1	1	1
9 "	6	3	2	2	...	...
10 "	10	2	...	...	...	...
11 "	19	3	...	...	...	...
12 "	9	1	...	2	...	...
13 "	11	...	...	1	1	...
14 "	4	...	...	...	...	...
15 "	3	1	...	...	...	...
17 " .....	...	...	...	1	...	...
18 "	1	...	...	...	...	...
Total.....	97	18	88	91	20	34

Average height of Pine—60-70 feet.

Diameter of average Pine over six inches—10.2 inches.

Diameter of average Pine over ten inches—11.8 inches.

Diameter of average Pine under ten inches—6.2 inches.

Volume of Pine over ten inches—5,760 board feet.

Volume of Pine under ten inches—3.5 cords (est.).

Average diameter of hardwoods—3.9 inches.

Volume of hardwoods—5.5 cords (est.).

Soil—dry white sand. Flat.

Ground burned over annually.

Density—about 0.6.

One Acre of Old Pine Near Winslow, New Jersey.

Diameter breast high.	Shortleaf Pine.	Pitch Pine.	Pine Stumps.	White Oak.	Black Oak.	Chestnut Oak.	Post Oak.	Hickory.
3 Inches.....	...	...	...	11	7	1	1	1
4 "	1	...	...	19	18	4	...	...
5 "	1	...	...	12	27	3	1	1
6 "	3	...	...	7	24	2	...	...
7 " .....	...	1	...	4	13	2	...	...
8 "	1	...	...	3	5	1	...	...
9 "	2	1	...	1	2	2	...	...
10 "	1	...	...	1	2	1	1	...
11 "	1	...	...	1	...	2	...	...
12 "	5	...	2	1	...	...	1	...
13 "	4	1	1	2	...	...	...	...
14 "	8	...	...	2	...	...	...	...
15 "	3	...	...	1	...	...	...	...
16 "	3	...	...	...	...	...	...	...
17 "	3	1	...	1	...	...	...	...
18 "	1	...	...	...	...	...	...	...
19 "	1	...	...	1	...	...	...	...
20 "	1	...	...	...	...	...	...	...
Total.....	39	4	3	67	98	18	4	2

Average height of Pine—68 feet.

Diameter of average Pine over six inches—13.1 inches.

Diameter of average Pine over ten inches—14.1 inches.

Total volume of Pine over six inches—1,613 cubic feet.

Merch. volume of Pine over ten inches—5,631 board feet.

Volume of Pine under six inches—0.03 cords (est.).

Average diameter of hardwoods—6.3 inches.

Volume of hardwoods—0.3 cords (est.).

Soil—dry sand. Flat.

Humus—rather poor.

Density—0.5.

The Pine stumps have been reckoned as trees in the computation of volume.

*One Acre of Old Pine, Mixed With Young Oak, Near New Lisbon,
Burlington County, New Jersey.*

Diameter breast high.	Shortleaf Pine.	Pine Stumps.	White Oak.	Black Oak.	Chestnut Oak.	Post Oak.
1 Inch.....	3	...	18	7	5	...
2 Inches	1	...	18	13	19	2
3 "	8	...	13	13	24	...
4 "	5	...	14	10	26	...
5 "	2	...	7	10	24	1
6 "	4	...	13	10	6	...
7 "	4	2	3	...	8	1
8 "	2	...	1	3	...	...
9 "	5	1	1	...	...	...
10 "	7	...	2	...	...	...
11 "	4	...	1	...	...	...
12 "	17	3	1	...	...	...
13 "	4	3	...	...	...	...
14 "	4	...	...	...	...	...
15 "	4	2	1	...	...	...
16 "	1	...	1	...	...	...
19 "	2	...	...	...	...	...
Total.....	77	11	94	66	112	4

Average height of Pine—60-70 feet.

Diameter of average Pine over six inches—10.1 inches.

Diameter of average Pine over ten inches—12.8 inches.

Diameter of average Pine under ten inches—4.7 inches.

Volume of Pine over ten inches—5,200 board feet.

Volume of Pine under ten inches—1.5 cords (est.).

Average diameter of hardwoods—3.8 inches.

Volume of hardwoods—6 cords (est.).

Soil—dry white sand. Flat.

Ground burned over annually.

Density—0.6.

One Acre of Old Pine Near Winslow, New Jersey.

Diameter breast high.	Shortleaf Pine.	Pine Stumps.	White Oak.	Black Oak.	Chestnut Oak.	Post Oak.
3 Inches.....	6	...	2	7	1	...
4 "	6	...	3	20	...	...
5 "	11	...	...	24	1	...
6 "	5	...	...	40	...	...
7 "	7	...	...	19	...	...
8 "	5	...	...	9	...	...
9 "	10	...	...	2	...	...
10 "	6	...	...	3	...	...
11 "	4	1	...	...	...	...
12 "	5	...	...	1	1	1
13 "	5	1	1	...	...	...
14 "	5	...	...	...	...	...
15 "	4	...	2	...	1	...
16 "	2	...	1	...	...	...
17 " .....	...	...	1	...	...	...
18 "	1	...	1	...	...	...
19 "	1	...	1	...	...	...
20 " .....	...	...	1	...	...	...
21 " .....	...	...	2	...	...	...
22 " .....	...	...	...	...	...	...
23 " .....	...	...	1	...	...	...
27 " .....	...	...	1	...	...	...
Total.....	83	2	17	125	4	1

Average height of Pine—67 feet.

Diameter of average Pine over six inches—11.0 inches.

Diameter of average Pine over ten inches—13.1 inches.

Total volume of Pine over six inches—1,708 cubic feet.

Merch. volume of Pine over ten inches—4,618 board feet.

Volume of Pine under six inches—0.5 cords (est.).

Average diameter of hardwoods—6.9 inches.

Volume of hardwoods—11.0 cords (est.).

Soil—dry sand. Flat.

Density—0.5-0.6.

The Pine stumps have been reckoned as trees in the computation of volume.

*One Acre of Old Pine, Mixed with Young Oak, near New Lisbon,
Burlington County, New Jersey.*

Diameter at breast high.	Shortleaf Pine.	Pitch Pine.	Pine stumps.	Black Oak.	White Oak.	Chestnut Oak.	Post Oak
1 Inch.....	...	...	...	...	4	...	...
2 Inches.....	5	...	...	10	19	15	4
3 "	7	...	...	33	23	39	6
4 "	6	...	...	33	31	38	2
5 "	2	...	...	16	20	21	2
6 "	5	...	1	14	13	20	...
7 "	8	1	...	8	4	3	...
8 "	2	...	1	1	1	1	...
9 "	7	...	...	1	...	...	...
10 "	9	...	...	...	...	...	...
11 "	15	...	2	...	...	...	...
12 "	10	...	1	...	...	...	...
13 "	3	...	4	...	1	...	...
14 "	1	...	2	...	...	...	...
15 "	4	...	...	...	...	...	...
16 "	1	...	...	...	...	...	...
19 " .....	...	...	1	...	...	...	...
Total.....	85	1	12	116	116	137	14

Average height of Pine--60-70 feet.

Diameter of average Pine over six inches--10.7 inches.

Diameter of average Pine over ten inches--12.0 inches.

Diameter of average Pine under ten inches--5.5 inches.

Volume of Pine over ten inches--4,500 board feet.

Volume of Pine under ten inches--2.5 cords (est.).

Average diameter of hardwoods--4.1 inches.

Volume of hardwoods--9 cords (est.).

Soil--dry white sand. Flat.

Ground burned over annually.

Density--0.6.

*One Acre of Old Pine, Mixed With Young Oak, Near New Lisbon,
Burlington County, New Jersey.*

Diameter breast high.	Shortleaf Pine.	White Oak.	Black Oak.	Chestnut Oak.	Post Oak.
1 Inch.....	32	3	2	...	4
2 Inches.....	50	11	2	1	8
3 "	30	23	3	3	7
4 "	25	13	12	...	7
5 "	18	6	...	1	4
6 "	25	1	2	3	3
7 "	9	...	...	...	...
8 "	10	...	...	...	...
9 "	9	...	...	...	...
10 "	6	...	...	...	...
11 "	10	...	...	...	...
12 "	11	...	...	...	...
13 "	3	...	...	...	...
14 "	4	...	...	...	...
15 "	2	...	...	...	...
18 "	1	...	...	...	...
	—	—	—	—	—
Total.....	245	57	21	8	33

Average height of Pine—60-70 feet.

Diameter of average Pine over six inches—9.0 inches.

Diameter of average Pine over ten inches—12.0 inches.

Diameter of average tree under ten inches—3.4 inches.

Volume of Pine over ten inches—3,700 board feet.

Volume of Pine under ten inches—4.0 cords (est.).

Average diameter of hardwoods—3.1 inches.

Volume of hardwoods—2 cords (est.).

Soil—dry white sand. Flat.

Ground burned over annually.

Density—0.7.

One Acre of Old Pine Near Winslow, New Jersey.

Diameter breast high.	Shortleaf Pine.	White Oak.	Black Oak.	Chestnut Oak.	Post Oak.	Black Jack Oak.
3 Inches.....	3	10	4	4	...	...
4 "	5	13	10	4	1	2
5 "	9	4	20	4	2	...
6 "	6	4	18	3	...	...
7 "	6	4	8	3	...	...
8 "	12	1	6	2	1	...
9 "	6	1	5	1	2	...
10 "	5	2	4	1	...	...
11 "	3	3	3	...	1	...
12 "	5	...	...	2	...	...
13 "	5	1	...	...	...	...
14 "	4	...	...	1	...	...
15 "	2	1	...	...	...	...
16 "	3	...	...	...	...	...
17 " .....	...	2	...	1	...	...
Total.....	74	46	78	26	7	2

Average height of Pine—67 feet.

Diameter of average Pine over six inches—10.4 inches.

Diameter of average Pine over ten inches—12.8 inches.

Total volume of Pine over six inches—1,275 cubic feet.

Merch. volume of Pine over ten inches—3,369 board feet.

Volume of Pine under six inches—0.3 cords (est.).

Average diameter of hardwoods—6.3.

Volume of hardwoods—9 cords (est.).

Soil—dry sand. Flat.

Humus—rather poor.

Density—0.5-0.6.

One Acre of 80-Year Old Second-Growth Pine at Winslow, New Jersey.

Diameter breast high.	Shortleaf Pine.	Pitch Pine.	Pine Stumps.	Oak.	Holly.
2 Inches.....	...	...	...	86	...
3 "	2	...	...	9	1
4 "	2	...	...	4	1
5 "	9	...	...	...	...
6 "	38	...	...	...	...
7 "	53	2	6	...	...
8 "	53	1	...	...	...
9 "	39	2	6	...	...
10 "	31	1	7	...	...
11 "	6	...	10	...	...
12 " .....	...	...	13	...	...
13 " .....	...	...	2	...	...
14 " .....	...	...	1	...	...
15 "	1	...	...	...	...
16 " .....	...	1	...	...	...
Total.....	234	7	45	99	2

Average height--65 feet.

Average diameter over six inches--8.6 inches.

Average age--80 years.

Total volume over six inches, without branches--4,339 cubic feet.

Merch. volume over ten inches--7,397 board feet.

Merch. volume over six inches--15,978 board feet.

Density--1.0.

Soil--rather dry, loamy sand. Flat.

Humus and litter--deep.

The Pine stumps have been reckoned as trees in the computation of volume.

One Acre of 80-Year Old Second-Growth Pine at Winslow, New Jersey.

Diameter breast high.	Shortleaf Pine.	Pitch Pine.	Pine Stumps.	Oak.	Holly.	Cedar
1 Inch.....	...	...	...	42	4	...
2 Inches.....	2	...	...	56	2	...
3 ".....	4	...	...	29	4	1
4 ".....	5	...	...	12	2	...
5 ".....	23	...	2	5	...	...
6 ".....	47	...	2	...	...	...
7 ".....	61	...	3	...	...	...
8 ".....	51	...	2	...	...	...
9 ".....	37	2	1	...	...	...
10 ".....	25	2	1	...	...	...
11 ".....	9	1	14	...	...	...
12 ".....	...	2	11	...	...	...
13 ".....	...	2	9	...	...	...
14 ".....	...	...	3	...	...	...
15 ".....	...	...	2	...	...	...
Total.....	264	9	50	144	12	1

Average height—65 feet,

Average diameter over six inches—8.9 inches.

Average age—80 years.

Total volume over six inches, without branches—4,483 cubic feet.

Merch. volume over 10 inches—7,604 board feet.

Merch. volume over six inches—16,993 board feet.

Density—1.0.

Soil—rather dry, loamy sand. Flat.

Humus and litter—deep.

The Pine stumps have been reckoned as trees in the computation of volume.

One-half Acre of Second-Growth Pitch Pine Near Tuckerton, New Jersey.

Diameter breast high.	Pitch Pine.	Pine Stumps
4 Inches.....	2
5 "	5	1
6 "	6	1
7 "	19	4
8 "	26	1
9 "	22	2
10 "	20	4
11 "	22	1
12 "	18	2
13 "	7	2
14 "	7
15 "	5	1
16 "	2
19 "	2
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Total.....	161	21

Average height—45-50 feet.

Average diameter—9.8 inches.

Average age—50 years.

Volume—24 cords (est.).

Soil—dry white sand. Flat.

Humus—poor.

Density—0.8.

The stumps have been reckoned as trees in the computation of volume.

One-half Acre of Second-Growth Pitch Pine, Near Whitings, New Jersey.

Diameter breast high.	Pitch Pine.
1 Inch.....	11
2 Inches	19
3 "	23
4 "	33
5 "	33
6 "	39
7 "	28
8 "	22
9 "	18
10 "	12
11 "	3
Total.....	241

Average height—45-50 feet.

Average diameter—6.6 inches.

Average age of small trees—35-40 years ; of large trees—50-60 years.

Volume—17 cords (est.).

Soil—white sand. Flat.

Humus—good.

Density—0.7.

One Acre of Second-Growth Pitch Pine Near Whitings, New Jersey.

Diameter breast high.	Pitch Pine.
1 Inch.....	26
2 Inches	52
3 "	51
4 "	83
5 "	88
6 "	90
7 "	89
8 "	45
9 "	28
10 "	14
11 "	4
12 "	2
13 "	1
Total.....	573

Average height—45-50 feet.

Average diameter—5.2 inches.

Average age of small trees—35-40 years ; of large trees—50-60 years.

Volume—21 cords (est.).

Soil—white sand. Flat.

Humus—good.

Density—0.8.

Three-quarters Acre of Second-Growth Shortleaf Pine Near Winslow, N. J.

Diameter breast high.	Shortleaf Pine.	Oak.	Hickory.
1 Inch.....	3	60	5
2 Inches.....	1	44	2
3 "	20	30	...
4 "	27	19	...
5 "	36	8	...
6 "	39	2	...
7 "	24	...	...
8 "	25	...	...
9 "	21	1	...
10 "	18	...	...
11 "	8	...	...
12 "	1	...	...
Total.....	223	164	7

Average height—45 feet.

Average diameter—6.6 inches.

Average age—55 years (est.).

Volume of Pine—15.0 cords (est.).

Soil—loamy sand. Flat.

Undergrowth composed of young Oaks, Holly, Vaccinium, and Inkberry.

Humus—fair.

Density--0.7.

*One-fourth Acre Second-Growth Shortleaf Pine, Near Brown's Mills,
New Jersey.*

Diameter breast high.	Shortleaf Pine.
1 Inch.....	2
2 Inches.....	18
3 "	63
4 "	101
5 "	49
6 "	24
7 "	9
8 "	1
Total.....	272

Average height--30 feet (est.).

Average diameter--4.4 inches.

Average age—40 years (est.).

Volume—20 cords (est.).

Soil—white sand. Flat.

Humus—good.

Density--0.9.

One-half Acre of Second-Growth Pitch Pine, Near Whitings, New Jersey.

Diameter breast high.	Pitch Pine.
1 Inch.....	23
2 Inches.....	51
3 ".....	57
4 ".....	54
5 ".....	49
6 ".....	37
7 ".....	26
8 ".....	37
9 ".....	18
10 ".....	9
11 ".....	1
Total.....	262

Average height—45-50 feet.

Average diameter—4.8 inches.

Average age of small trees—35-40 years; of large trees—50-60 years.

Volume—10 cords (est.).

Soil—white sand. Flat.

Humus—good.

Density—0.9-1.0.

One-half Acre of Second-Growth Pitch Pine, Near Whitings, New Jersey.

Diameter breast high.	Pitch Pine.
1 Inch.....	11
2 Inches.....	27
3 ".....	23
4 ".....	32
5 ".....	41
6 ".....	48
7 ".....	45
8 ".....	21
9 ".....	12
10 ".....	5
12 ".....	1
Total.....	266

Average height—45-50 feet.

Average diameter—5.3 inches.

Average age of small trees—35-40 years; of large trees—50-60 years.

Volume—9 cords (est.).

Soil—white sand. Flat.

Humus—good.

Density—0.75.

One Acre of Second-Growth Pitch Pine Near Whitings, New Jersey.

Diameter breast high.	Pitch Pine.
1 Inch	7
2 Inches.....	33
3 "	75
4 "	132
5 " ..	129
6 "	95
7 " ..	54
8 "	22
9 "	7
10 "	2
11 "	2
12 "	1
Total.....	559

Average height—45-50 feet.

Average diameter—4.8 inches.

Average age of small trees—35-40 years; of large trees—50-60 years.

Volume—13.5 cords (est.).

Soil—white sand. Flat.

Humus—good.

Density—0.8.

One Acre of Second-Growth Pitch Pine Near Whitings, New Jersey.

Diameter breast high.	Pitch Pine.
1 Inch	18
2 Inches.....	30
3 "	44
4 "	43
5 "	76
6 "	80
7 "	30
8 " ..	40
9 "	21
10 "	17
11 "	9
12 "	2
Total.....	410

Average height—45-50 feet.

Average diameter—5.3 inches.

Average age of small trees—35-40 years; of large trees—50-60 years.

Volume—14 cords (est.).

Soil—white sand. Flat.

Humus—good.

Density—0.7.

*One-quarter Acre of 30-40 Year Old Pitch Pine Coppice, near Whitings,
New Whitings.*

Diameter breast high.	Pitch Pine.
2 Inches.....	40
3 "	85
4 "	62
5 "	42
6 "	12
7 "	5
8 "	1
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Total.....	247

Average height—24 feet.

Average diameter—37 inches.

Average age—35-40 years.

Volume—3.3 cords.

Soil—sand. Flat.

Humus—good.

Density—1.0.

*Three-tenths Acre of Pitch Pine Coppice, near Whitings, New Jersey,
which had been Cut and Stacked.*

Diameter breast high.	Pine Stumps.
2 Inches.....	27
3 "	50
4 "	47
5 "	17
6 "	17
7 "	9
8 "	1
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Total.....	168

Average height—about 25 feet.

Average diameter—3.9 inches.

Average age—35-40 years.

Volume—slightly over two cords.

Density—0.8.

Soil—sand. Flat.

One Acre Near Ong's Hat, Burlington County, New Jersey, Showing the Condition of Second-Growth Pine in This Section.

Diameter breast high.	Pitch Pine.
4 Inches.....	13
5 "	21
6 "	20
7 "	18
8 "	9
9 "	6
10 "	5
11 "	6
12 "	2
13 "	1
14 "	4
Total.....	105

Pine under two inches—74.

Small oak—113.

Average diameter—7.0 inches.

Volume—7.5 cords (est.).

Soil—fine sand. Flat.

Humus—very poor.

Ground cover—chiefly moss and leaf-litter.

Density—0.6.

One Acre Near West Creek, Ocean County, New Jersey, Showing the Condition of Less Severely Burned Land.

Diameter breast high.	Pitch Pine.
2 Inches.....	22
3 "	56
4 "	88
5 "	72
6 "	60
7 "	33
8 "	8
Total.....	339

Pine under two inches—73.

Small oak—389.

Average diameter—4.7 inches.

Volume—7 cords (est.).

Soil—fine sand. Flat.

Humus—fair.

Ground cover—Scrub Oaks.

Density—0.6.

One Acre of Pitch Pine on Burned Land Near Ong's Hat, Burlington County, New Jersey.

Diameter breast high.	Pitch Pine.	Oak.
2 Inches.....	1	...
3 "	12	...
4 "	12	...
5 "	12	...
6 "	18	1
7 "	15	...
8 "	10	...
9 "	3	...
10 "	9	...
11 "	4	...
12 "	1	...
13 "	1	...
Total.....	98	1

Average height—25-30 feet.

Average diameter—6.4 inches.

Average age—30-40 years.

Volume—5 cords (est.).

Soil—white sand. Flat.

Ground cover—Scrub Oaks, Huckleberries, grass, etc.

Density—0.2.

One Acre Near the East Plains, Showing the Condition of Severely Burned Land.

Diameter breast high.	Pitch Pine.
2 Inches.....	12
3 "	28
4 "	44
5 "	42
6 "	32
7 "	26
8 "	5
Total.....	189

Pine under two inches—68.

Small Oak—208.

Average diameter—4.8 inches.

Volume—4 2 cords (est.).

Soil—fine sand. Flat.

Humus—good.

Ground cover—Scrub Oak.

Density—0.5.

*One Acre Near the Edge of the East Plains, Showing the Condition of
Pine Land Which Has Been Frequently Burned.*

Diameter breast high.	Pitch Pine
2 Inches	11
3 "	14
4 "	29
5 "	36
6 "	27
7 "	28
8 "	20
9 "	6
Total.....	<hr/> 171

Pine under two inches—13.

Small Oak—142.

Average diameter—4.8 inches.

Volume—4.2 cords (est.).

Soil—gravelly sand. Flat.

Humus—burned off.

Ground cover—Scrub Oaks.

Density—0.2.

*One Acre of Pitch Pine on Burned Land Near Ong's Hat, Burlington
County, New Jersey.*

Diameter breast high.	Pitch Pine.
2 Inches	9
3 "	15
4 "	10
5 "	10
6 "	12
7 "	14
8 "	13
9 " .....	...
10 "	7
11 "	3
12 "	1
Total.....	<hr/> 94

Average height—25-30 feet.

Average diameter—5.7 inches.

Average age—30-40 years.

Volume—3.1 cords (est.).

Soil—white sand. Flat.

Ground cover—Scrub Oaks, Huckleberries, grass, etc.

Density—0.2.

One Acre Near the East Plains, Showing the Condition of Severely Burned Land.

Diameter breast high.	Pitch Pine.
2 Inches.....	5
3 "	12
4 "	34
5 "	36
6 "	16
7 "	12
8 "	4
9 "	2
Total.....	<hr/> 121

Pine under two inches—78.

Small Oak—708.

Average diameter—4.9 inches.

Volume—2.8 cords (est.).

Soil—fine sand. Flat.

Humus—fair.

Ground cover—a heavy growth of Scrub Oak.

Density—0.2.

One Acre Near the East Plains, Showing the Condition of the Forest on Repeatedly Burned Land.

Diameter breast high.	Pitch Pine.
2 Inches.....	54
3 "	111
4 "	44
5 "	12
Total.....	<hr/> 221

Pine under two inches—466.

Small Oak—312.

Average diameter—3.1 inches.

Soil—coarse sand with some gravel. Flat.

Humus—scant.

Ground cover—Pine and Oak sprouts.

Density—0.1.

*One Acre at Spring Hill, Near the West Plains, Showing the Condition of
the Pine on Repeatedly Burned Land.*

Diameter breast high.	Pitch Pine.
2 Inches.....	64
3 "	48
4 "	34
5 "	26
6 "	19
7 "	5
8 "	2
9 "	2
Total.....	200

Pine under two inches—77.

Small Oak—34.

Average diameter—3.6 inches.

Volume—2.6 cords (est.).

Soil—Gravelly sand. Flat.

Humus—Very poor.

Density—0.4.

One Acre of Recently Burned Pine Coppice, Near Tuckerton, New Jersey.

Diameter breast high.	Sprouting in the Crown	Pitch Pine, Dead.	Sprouting at the Stump.
1 Inch	1	58	45
2 Inches.....	6	70	57
3 "	21	56	25
4 "	27	30	3
5 "	12	14	...
6 "	5	1	...
7 "	1	1	...
Total.....	73	230	130

Average height—about 20 feet.

Average age—25-30 years.

Average diameter of Pine sprouting in crown—5.5 inches.

Average diameter of Pine sprouting at stump—4.8 inches.

Average diameter of the dead Pine—6.4 inches.

One Acre Near the East Plains, Showing the Condition of Severely Burned Land.

Diameter breast high.	Pitch Pine.
2 Inches	20
3 " 	81
4 " 	62
5 " 	12
6 " 	2
Total.....	177

Pine under two inches—386.

Small Oak—250.

Average diameter—3.4 inches.

Soil—fine sand. Flat.

Humus—poor.

Density—0.1.

One Acre Near Ong's Hat, Burlington County, New Jersey, Showing the Condition of the Second-Growth Forest After it has Begun to Deteriorate Through Fire.

Diameter breast high.	Pitch Pine.
2 Inches	35
3 " 	7
4 " 	18
5 " 	23
6 " 	12
7 " 	9
8 " 	6
9 " 	8
Total.....	118

Pine under two inches—108.

Small Oak—162.

Average diameter—4.4 inches.

Volume—2.2 cords (est.).

Soil—fine sand with some gravel. Flat.

Humus—scant.

Area has been periodically burned.

Density—0.4.

*One Acre, near Tuckerton, Ocean County, New Jersey, Showing the
Condition of Pine Land which has been
Repeatedly Burned.*

Diameter breast high.	Pitch Pine.
2 Inches.....	3
3 "	20
4 "	42
5 "	32
6 "	12
7 "	4
8 "	1
<hr/>	
Total.....	114

Pine under two inches—139.

Small Oak—274.

Average diameter—4.4 inches.

Volume—21 cords (est.).

Soil—gravelly sand. Flat.

Humus—burned off.

Ground cover—stunted Oak sprouts.

Density—0.3.

One Acre near the Middle of the East Plains.

Diameter breast high.	Pitch Pine.
2 Inches.....	76
3 "	62
4 "	43
5 "	8
6 "	2
<hr/>	
Total.....	161

Pine under two inches—436.

Small Oak—864.

Average height—18-20 feet.

Average age—about 40 years.

Situation—high ground.

Soil—dry, coarse, gravelly sand. Flat.

Small patch of a few acres surrounded on all sides by prostrate coppice.

*One Acre Near the East Plains, Showing the Condition of Severely
Burned Land.*

Diameter breast high.	Pitch Pine.
2 Inches.....	14
3 "	16
4 "	12
5 "	24
6 "	10
7 "	11
8 "	3
Total.....	90

Pine under two inches—36.

Small Oak—411.

Average diameter—4.5 inches.

Volume—1.7 cords (est.).

Soil—gravelly sand. Flat.

Humus—fair.

Ground cover—scrub Oaks.

Density—0.2.

*One Acre at Spring Hill Near the West Plains, Showing the Condition of
Pine Land Which is Burned Over on an Average Every
Two or Three Years.*

Diameter breast high.	Pitch Pine.	Oak.
2 Inches.....	43	56
3 "	34	19
4 "	41	8
5 "	17	...
Total.....	135	83

Pine under two inches—62.

Small Oak—147.

Average diameter—3.2 inches.

Soil—gravelly sand. Flat.

Humus—nearly wanting.

Ground cover—stunted coppice growth of Pine and Oak.

Density—0.3.

One Acre of Pitch Pine on Burned Land, Near Ong's Hat, Burlington County, New Jersey.

Diameter breast high.	Pitch Pine.
2 Inches.....	2
3 "	6
4 "	6
5 "	7
6 "	10
7 "	2
8 "	1
9 "	2
10 "	5
Total.....	41

Average height—25-30 feet.

Average diameter—5.5 inches.

Average age—30-40 years (est.).

Volume—1.3 cords (est.).

Soil—white sand. Flat.

Ground cover—Scrub Oaks, Huckleberries, grass, etc.

Density—0.2.

One Acre of Recently Burned Pine Coppice Near Tuckerton, New Jersey.

Diameter breast high.	Sprouting in the Crown.	Pitch Pine. Dead.	Sprouting at the Stump.
2 Inches	5	20	...
3 " .....	...	20	2
4 "	3	17	3
5 "	6	16	6
6 "	3	20	1
7 "	4	15	4
8 "	2	9	1
9 "	2	4	4
10 "	1	...	1
11 " .....	...	...	1
Total.....	26	121	23

In addition, 41 Pine sprouts, 11 Pine seedlings, and 102 Oak sprouts were counted.

Average height—20-30 feet.

Average age—about 30 years.

Average diameter of Pine sprouting in crown—4.2 inches.

Average diameter of Pine sprouting at stump—1.9 inches.

Average diameter of the dead Pine—2.4 inches.

*One Acre of Recently Burned Pine Land Near Tuckerton, New Jersey.
Trees Chiefly Sprouts.*

Diameter breast high.	Pitch Pine.
3 Inches.....	3
4 ".....	2
5 ".....	1
6 ".....	3
7 ".....	3
8 ".....	1
9 ".....	1
Total.....	14

Average height—20 feet.

Average diameter—5.5 inches.

Average age—30 years.

Volume— $\frac{1}{2}$ cord (est.).

*One-Quarter Acre of White Cedar, 66 Years Old, on the Stump, in
Marigold Swamp, near New Gretna, Burlington County, New Jersey.*

Diameter breast high.	White Cedar.	Magnolia.	Gum.
2 Inches.....	2	1	...
3 ".....	11	...	...
4 ".....	28	2	...
5 ".....	47	...	1
6 ".....	59	...	...
7 ".....	34	...	..
8 ".....	36	...	1
9 ".....	23	...	...
10 ".....	8	...	...
11 ".....	2	...	...
12 ".....	2	...	...
13 ".....	1	...	...
Total.....	253	3	2

Average height—60 feet.

Average diameter—6.6 inches.

Average age—66 years.

Total volume per acre—7,693 cubic feet.

Merch. volume per acre—14,636 board feet.

Number of rails in addition—1,568.

Soil—wet mud. Flat.

Ground cover—Laurel, Inkberry, Sweep Pepper Bush, &c.

Density—1.0.

One-quarter Acre of White Cedar, 66 Years Old on the Stump, in Marigold Swamp, Near New Gretna, Burlington County, New Jersey.

Diameter breast high.	White Cedar.	Sweet Birch.
3 Inches.....	3	...
4 "	9	...
5 "	31	1
6 "	31	...
7 "	42	...
8 "	47	...
9 "	23	...
10 "	20	...
11 "	6	...
12 "	1	...
13 "	1	...
Total.....	214	1

Average height—60 feet.

Average diameter—7.2 inches.

Average age—66 years.

Total volume per acre—7,448 cubic feet.

Merch. volume per acre—18,244 board feet.

Number of rails in addition—1,416.

Soil—wet mud.

Ground cover—Laurel, Magnolia, High-Bush Blueberry, Inkberry, etc.

Density—1.0.

One-quarter Acre of White Cedar, 79 Years Old on the Stump, in Job's Swamp, Near Whitings, Ocean County, New Jersey.

Diameter breast high.	White Cedar.	Birch.	Gum.	Magnolia.
2 Inches.....	...	...	1	3
3 "	88	...	2	...
4 "	42	...	...	...
5 "	49	1	...	...
6 "	47	...	...	...
7 "	33	...	...	...
8 "	33	...	...	...
9 "	25	1	...	...
10 "	17	...	...	...
11 "	2	...	...	...
12 "	7	...	...	...
Total.....	263	2	3	3

Average height—60 feet.

Average diameter—6.9 inches.

Average age—79 years.

Total volume per acre—7,624 cubic feet.

Merch. volume per acre—15,596 board feet.

Number of rails in addition—1,472.

Soil—wet mud. Flat.

Ground cover—Laurel, Magnolia, High Bush Huckleberry, etc.

Density—1.0.

One-quarter Acre of White Cedar, 62 Years Old on the Stump, in Job's Swamp, Near Whitings, Ocean County, New Jersey.

Diameter at breast high.	White Cedar.	Dead Cedar.	Magnolia.	Maple.	Gum.	Sweet Birch.
1 Inch	5	...	6	...	...	...
2 Inches.....	17	5	11	...	...	...
3 "	57	16	2	1	1	...
4 "	61	1	2	...	...	...
5 "	62	2	...	...	...	...
6 "	54	...	...	...	...	...
7 "	44	...	...	...	...	1
8 "	16	...	...	...	...	...
9 "	8	...	...	...	...	...
10 "	6	...	...	...	...	...
11 "	1	...	...	...	...	...
	<hr/> 331	<hr/> 24	<hr/> 21	<hr/> 1	<hr/> 1	<hr/> 1

Average height—48.5 feet.

Average diameter—5.4 inches.

Average age—62 years.

Total volume per acre—5,868 cubic feet.

Merch. volume per acre—9,756 board feet.

Number of rails in addition—2,420.

Soil—wet mud. Flat.

Ground cover—Laurel, Holly, Inkberry, High Huckleberry, etc.

Density—1.0.

One-quarter Acre of White Cedar, 80 Years Old on the Stump, in Job's Swamp, Near Whitings, Ocean County, New Jersey.

Diameter breast high.	White Cedar.	Dead Cedar.	Maple.	Gum.	Sweet Birch.	Holly.
2 Inches.....	...	...	...	...	3	2
3 ".....	...	...	2	1	4	...
4 ".....	...	7	5	...	2	...
5 ".....	6	14	1	1	2	...
6 ".....	5	13	1	...	1	...
7 ".....	12	2	2	1	...	...
8 ".....	22	3	2	...	1	...
9 ".....	29	3	1	...	1	...
10 ".....	18	2	...	...	...	...
11 ".....	21	1	...	...	1	...
12 ".....	7	...	...	...	...	...
13 ".....	7	...	...	...	...	...
14 ".....	10	...	...	...	...	...
15 ".....	3	...	...	...	...	...
Total.....	140	45	14	3	15	2

Average height—65 feet.

Average diameter—9.2 inches.

Average age—80 years.

Total volume per acre—8,910 cubic feet.

Merch. volume per acre—25,668 board feet.

Number of rails in addition—692.

Soil—wet mud. Flat.

Ground cover—Laurel, Holly, Maple, Inkberry, etc.

Density—0.8.

One-quarter Acre of White Cedar, 49 Years Old on the Stump, in Job's Swamp, near Whitings, Ocean County, New Jersey.

Diameter breast high.	White Cedar.	Sweet Birch.	Magnolia.	Maple.
1 Inch.....	2	2	3	1
2 Inches.....	20	9	9	2
3 ".....	113	3	...	...
4 ".....	132	...	...	...
5 ".....	102	...	...	...
6 ".....	62	...	...	...
7 ".....	40	...	...	...
8 ".....	3	...	...	...
Total.....	474	14	12	3

Average height—42 feet.

Average diameter—4.6 inches.

Average age—49 years.

Total volume per acre—5,286 cubic feet.

Number of rails—2,676.

Soil—wet mud. Flat.

Ground cover—Laurel, High Bush Huckleberry, etc.

Density—0.9.

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